VOL. 3

UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS, } ss.
EASTERN DIVISION.

IN THE

District Court of the United States

UNITED STATES OF AMERICA,
Complainant,
vs.
THE SANITARY DISTRICT OF CHICAGO,
Defendant,

C. C. No. 29,019, and
Equity No. 114.

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

MR. JAMES H. WILKERSON,
United States Attorney, and
MR. ALBERT L. HOPKINS,
Assistant United States Attorney,
For Complainant.
MR. EDMUND D. ADCOCK and
MR. ALFRED S. AUSTRIAN,
For Respondent.

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VOL. III.

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Defendants'.

1913

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The deposition of JOHN R. FREEMAN, taken pursuant to notice, before Samuel M. Morgan, Commissioner, on the 4th day of April, A. D. 1913, at the offices of Messrs. Mayer, Meyer, Austrian & Platt, Chicago, Illinois.

Present:

Mr. James H. Wilkerson, on behalf of the Government;
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian, on behalf of the Sanitary District.

Mr. Wilkerson: I assume that the testimony of this witness may be taken under the same arrangement as to objections and motions to strike as was made with regard to the other witnesses.

Mr. Adcock: Yes.

Mr. Wilkerson: I will reserve those objections and motions then, so as not to interrupt.

JOHN R. FREEMAN, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your full name?
A. John R. Freeman.
Q. What is your residence?
A. Providence, Rhode Island.
Q. What business are you in?
A. Civil engineer, making a specialty of hydraulic work.
Q. And your office is at Providence, Rhode Island?
A. Providence, Rhode Island; also New York City; and have a Boston office also.
Q. Will you state your early training, your experience, and what official positions, of honor or otherwise, as civil engineer, you have held?
A. I graduated in the civil engineering course at the Massachusetts Institute of Technology thirty-seven years ago. Since that time I have been continuously in the practice of civil engineering, making a specialty of hydraulic work, such as water power development and municipal water supply. For ten years, from 1876 to 1886, was principal assistant engineer of the Water Power Company controlling the Merrimac river at Lawrence, Massachusetts, where a large part of my duties were connected with measuring the quantity of water used from day to day by the various factories, and in measuring the flow of the Merrimac river.

During this time I also acted as principal assistant to Mr. Hiram F. Mills, in consulting engineering, which embraced water power work on various rivers; and I had charge of measuring the water used by the factories at Manchester, New Hampshire; also had charge of investigations for water power development at Concord, New Hampshire, which involved studying the flow of the river and making gagings of it. During this period I had supervision in detail of many experiments in hydraulics made by Mr. Mills, which involved the devising of methods for the accurate measurement of flowing water, and studies of the yield of the watersheds of rivers, and studies of evaporation.

I was a member of the Metropolitan Water Board of Massachusetts, which Board was appointed in 1895 to plan and

build the water works for the supply of about fifteen municipalities, of which Boston is the center and chief city.

For two years, about five years ago, I was principal consulting engineer to the New York State Water Supply Commission.

For twelve years, I have been almost continuously engaged as consulting engineer to the City of New York, in connection with the improvement and enlargement of its water supply. This work has involved estimating the yield from many watersheds, and studying the evaporation from great reservoirs.

I was for several years consulting engineer to the water works at Nashua, New Hampshire; and have been consulting engineer to various other municipalities, relative to their water supply. Among these was the city of Los Angeles, California, with reference to its new supply from the Owens river; and the City of Baltimore on the extension of its water works. And for three years past, and at present am consulting engineer to the City of San Francisco in the development of additional water supply, which involved the study of the yield of watersheds, and the evaporation from reservoirs.

Have been consulting engineer to the Mexican Government on the extension of the water supply of the City of Mexico. And for three years past, and at present am consulting engineer to the Canadian Government on matters of water power development on various rivers in Western Canada.

Have made extended studies of the obstructions to flow of rivers caused by ice, principally on the St. Lawrence river, and with reference to water power development at Masseua, New York; and in reference to the proposed Long Soo Water Power development on the St. Lawrence.

Have been consulting engineer to water power companies at Niagara Falls. For several years past, consulting engineer to the Mississippi River Power Company on various matters connected with the development of water power on the Mississippi river at Keokuk, Iowa; and have made special study of the ice obstruction to the flow of the Mississippi river at Keokuk.

Was a member of two Boards of Engineers appointed by the President to investigate matters connected with the building of the Panama Canal.

Planned water power developments of the Great Western Power Company on the Feather river, in California, which included a storage reservoir of forty square miles in area, re-

quiring extended studies of evaporation and yield of watersheds.

Have acted as consulting engineer to the United States Reclamation Service, in building the dam on the Boise river. Was consulting engineer to extensive irrigation works in Texas. Have made many experiments, personally, upon the flow of water; and am familiar with the methods of water measurements by current meters and various other devices. And have had practical experience with most of the devices in ordinary use for measuring the flow of rivers.

Q. Have you studied the reports of the Chief of Engineers of the United States Army from 1900 to 1912 inclusive, and the records of discharge measurements of the St. Clair, Niaraga and St. Lawrence rivers; and the statements made in the reports of the Chief of Engineers as to the amount by which the Great Lakes would be lowered by a diversion of 2, 4, 10, or 14,000 second feet through the Chicago Drainage Canal?

A. I have studied these reports in great detail.

Q. Have you studied the testimony of Mr. F. C. Shenehon, a witness for the complainant, and his statement that with 10,000 second feet diverted through the Chicago Drainage Canal these lakes would be lowered substantially as follows: Michigan-Huron, 5 inches; Erie, 5½ inches; Ontario, 4⅛ inches?

A. I have.

Q. Have you studied the testimony of Mr. Gardner S. Williams, a witness for the defendant or respondent in this case, and his methods of computing from the data described as given in the report of the Chief of Engineers, and the various exhibits in this case, from which he concludes that the lowering of the several lakes, assuming that the measurements of the St. Clair, Niagara and St. Lawrence were correct, will be substantially as follows: Huron, 4 1/6 inches; Erie, 3 2/3 inches; Ontario, 3.95 inches?

A. I have studied these carefully.

Q. Have you compared the data, and the selected methods used by Mr. Shenehon and Mr. Williams sufficiently to reach conclusions of your own as to which estimate is most nearly correct, assuming the records of the observations made by the Government on the St. Clair, Niagara and St. Lawrence rivers are correct?

A. I have made careful studies of the computations of both, and I find that both engineers start from substantially the same data; that Mr. Williams' results average about one-

fourth part smaller than Mr. Shenehon's, and that the difference in this result comes from differences of precision in the methods of computation.

The chief differences in these methods are, first, that in preparing the curve of discharge, consisting of a line upon a diagram for showing the increment or the rate of increase in discharge corresponding to one foot increase in height at the respective gaging stations, that apparently Mr. Shenehon, and the Government Engineers, have determined the relation of discharge to height by some such mechanical means of averaging the separate observations as by drawing a thread through the observations, or by making an approximate average by some such means of trial and error as drawing a random line and then measuring the distances of the several observations from this line, seeking to make the sum of the distances on the two sides of the line, for observations at about the same height, equal; which method is one commonly used by engineers for approximations.

On the other hand, I find that Mr. Williams for deducing his discharge curve and increment from the same observations has made use of a method of greater mathematical accuracy, which method I notice has been recently used under the name of the Three Point Method, by the Government Engineers, in certain of their more recent determinations of this same kind.

Second: I find that Mr. Shenehon and his associates, in the preparation of their discharge curve and increment in evidence in this case for determining the effect of the Chicago diversion upon the lake levels have, in the case of the St. Clair river, based their increment solely upon elevations observed in the St. Clair river near the outlet of Lake Huron, and have made no allowance for the effect upon the discharge of the varying elevation of Lake St. Clair.

On the other hand, I find that Mr. Williams, in his similar computations, has carefully made an allowance for the influence of the elevation of Lake St. Clair upon the discharge.

Third: I find that Mr. Shenehon and his associates, in preparing their discharge curve and increment presented in the testimony in this case, have, for the purpose of establishing their average values, included substantially all of the measurements of discharge that have been made, without discarding those in which the lake and the river were in such a changing and unstable condition that the regimen of flow was probably not well established.

On the other hand, I find that Mr. Williams has selected

out from the great number of discharge measurements those in which the lake and river had a nearly constant elevation for a sufficient time prior to the measurements, and during the measurements, so that a stable condition of flow was apparently secured.

To sum up the comparisons between the methods of Mr. Shenehon and his associates, in evidence in this case for establishing the relation of river discharge to height of lake, I find that the methods followed by Mr. Williams lead to a higher degree of accuracy, granting that the data from which both had started is correct. I have not myself attempted to check over all of the arithmetical computations of either party, nor have I personally replotted their diagrams; having assumed this work of arithmetic and drafting was correctly done in both cases; and having found, as I believe, a sufficient explanation for the difference of about five-sixths of an inch, in the case of Huron; about 1 3/4 inches in the case of Erie; and one-fourth of an inch in the case of Ontario, to be sufficiently explained by the difference in the precision of methods followed in the computation which I have described above.

Q. Assuming, as it is claimed by the Government witnesses, that the diversion of 10,000 second feet at Chicago would lower the lakes to an amount of 5 to 4 inches in each case, and that the average diversion through the Chicago Sanitary and Ship Canal during the past ten years has been approximately one-half of this amount, from which it might be inferred on the theory of the Government's witnesses that this actual diversion would have lowered these lakes from 2½ to 2 inches, respectively, have you studied the record of changes of lake levels with a view to determining the possibility of detecting the evidence of any such effect of lowering?

A. I have studied these records; and I find it plain that it would be utterly impossible to detect by direct measurement a lowering of this small magnitude, because of it being disturbed by the continual fluctuations in level of the lakes, which come from natural causes and which are of far greater magnitude.

Moreover, a lowering of this small magnitude would be obscured by the effects of far greater magnitude in lowering the lake levels resulting from the dredging by the Government in the improvement of navigation in the river channels.

I may add that this quantity of 5,000 second feet, which has been diverted, is only about 2½ per cent. of the average flow

at the points where the discharges of the lakes have been measured, which amount is smaller than the precision that can be attained in the most careful measurements of the discharge.

Q. Describe what these fluctuations are which render it, as you say, impossible to measure the effects of the magnitude claimed due to the diversion at Chicago?

A. In order to illustrate these more clearly, I have prepared a diagram, "J. R. F. Exhibit No. 1," extended to 1912 from the data shown upon Williams' Exhibit 26, which I submit to the Commissioner to be marked "John R. Freeman Exhibit 1."

Whereupon the diagram described by the witness was marked by the Commissioner "John R. Freeman Exhibit 1."

Q. Will you describe the exhibit which has just been identified and marked?

A. This bears the title: "Studies relative to Chicago Drainage Canal by John R. Freeman, March 17, 1913." At the top of the diagram I have traced curves showing the elevation of the Great Lakes month by month, throughout the entire period from 1860 to 1912; these curves being an exact copy of Plate No. 1 in the Report of the International Waterways Commission for the Regulation of Lake Erie for 1910.

To the right of this diagram I have drawn parallel lines separated by a distance measured upon the same scale as the diagram just referred to, which show the computed effect of the diversion by the Drainage Canal in lowering the lakes, based on the defendant's reduction of the complainant's observations; this lowering being estimated without regard to any compensation works. By comparing the dimensions corresponding to diversions of 4,000, 10,000 and 14,000 second feet with the range of fluctuation in the lake surfaces, from month to month and from year to year, it will be seen that the great fluctuation of the lake surface from natural causes obscures any lowering of the magnitude computed as due to the withdrawal of water through the Chicago Drainage Canal.

There are about six different kinds of oscillations or change in the lake levels, each of which is of far greater magnitude than that estimated to be caused by the diversion of the several quantities through the canal.

For example, we have first, the change of lake level which is dependent upon the varying quantity of rainfall from year to year.

A second kind of fluctuation in lake level is that resulting from the clogging of the outlets of the several lakes by ice, during the winter. This effect is particularly large in the case of Lakes Huron and Michigan; and results from ice cover in the St. Clair river, and occasionally is increased by ice gorges near the head of the St. Clair river. Both the ordinary ice cover and the ice gorge hold back the discharge from Lake Huron, and this causes the level of Lake Huren to rise, while at the same time causing the level of Lake Erie to fall. The magnitude of the change in level caused by ice varies greatly from year to year, in an extremely capricious manner, and to an extent which at present cannot be measured, throughout almost the entire period for which we have accurate lake levels.

This obstruction is extremely variable from year to year, and even from day to day, depending upon many causes con-

nected with wind and weather. The magnitude of the obstruction depends primarily upon the intensity of the cold weather and the duration of the period of extreme cold; and secondarily it is dependent upon the effect of wind in breaking off shore ice from near the outlet of the lake, which floating down through the narrow part of the St. Clair river where the water is open becomes crowded against and lodged beneath the ice covering the river, where it broadens out.

These ice effects were observed with considerable care by the United States engineers only in the year 1901, and at that time periods were found when the flow of the St. Clair river was cut down about one-half by ice. A reference to this may be found in the report of the Chief of Engineers for 1902, on pages 2835 and 2836.

On the other hand, in winters like that which we have just passed through, there would be little or no clogging of this kind. Obviously when the St. Clair River is thus clogged Lakes Huron and Michigan must rise, and Lake St. Clair and Erie must fall, because of the cutting off of their most important source of water supply. Lake Erie doubtless also suffers some impediment to its discharge, because of ice in the Niagara River. But the records indicate that the extent of this clogging is far less than in the St. Clair River.

Perhaps this is as good a place as any to go into this question of ice obstruction, in some detail. I regard this matter as extremely important, because I am led to believe that failure to appreciate its influence has led to serious error in the studies of the levels of the Great Lakes by the Government Engineers; and to the best of my judgment and belief, sufficient compensation for its effect has not been made in their computations and estimates of the yearly discharge of the several lakes, and in the relation of their levels.

From the following observations hereinafter stated, I am led to believe that the effect of ice obstruction, particularly in the case of Huron and Michigan, may be at times far greater than any possible change of level due to the diversion through the Chicago Drainage Canal. I have had occasion to make extended studies of the influence of both ice cover and ice gorges in lessening the discharge of rivers. By "ice cover," I mean the smooth covering of ice remaining in the place where it was formed, presenting a smooth surface to the flowing water on its under side. By an "ice gorge" is meant the condition that results from the ice on the shores of lake or river becoming broken off by wind or wave or change of level, and floating down the stream, and being drawn against

and beneath an ice cover further down the stream, at a point where freezing has occurred by reason of the velocity being less. Conditions of this character are presented in the St. Clair River within a few miles from the outlet of Lake Huron. They are also presented in the St. Lawrence River, particularly in the vicinity of Ogdensburg and in the vicinity of the Long Soo Rapids. To a less extent they are present in severe weather in the Niagara River.

I have had occasion to study these ice conditions in the St. Lawrence River very carefully in connection with the water power developments from the St. Lawrence near Massena, New York; and during the past winter have had occasion to study them on the Mississippi River in the vicinity of Keokuk, with particular relation to the water power now being developed by the dam across the Mississippi River at that point.

To a less degree, I have had occasion to study them in the Niagara River, and during some of the most extremely cold weather of the past winter have had occasion, in connection with my engineering work for one of the water power companies at Niagara, to personally observe the condition of ice formation in the Niagara River between Chippewa and the Falls.

Some of the data from which the conclusions stated above is reached are presented in the report of the Chief of Engineers for the year ending June 30, 1901, on pages 3765, et seq., wherein are described the discharge observations during the very severe ice conditions in the winter of 1900-1901. This states that, "The temperature conditions of the early winter were such that by January 20 Lake St. Clair and the St. Clair River were frozen over from its mouth to a point above Stag Island. The foot of Lake Huron had also frozen over, and what is known as the Ice Bridge had formed at Fort Gratiot. This left open water from a point just below Fort Gratiot to a point some little distance above Stag Island." (p. 3771—Report 1901.)

This section of open river permitted them to continue discharge measurements as usual, and it was found that almost immediately after the closing of the river in January, the discharge fell off approximately fifty per cent., and did not resume normal conditions of flow until the river became free of ice, about the middle of May.

During the general breaking up of the ice, immense masses of it were forced into the river by northerly winds and so choked the flow that for a time but very little water could have found its way through. For same days Lake St. Clair

was but a few inches above the level of Lake Erie. This condition of restricted flow has made itself manifest in the relative elevation of Lakes Huron and Erie, and we find that for the month just closed Lake Huron was 0.55 of a foot higher, while Lake Erie was 0.75 of a foot lower than during June, 1900. These fluctuations, it will be noted, are greater than those estimated to occur because of the present or prospective diversion through the drainage canal.

While the conditions in this year were doubtless uncommonly severe the record of temperatures indicates that something of this kind may frequently occur. And from my study of the levels of the Mississippi River during the ice season, for the past thirty years and more, and my studies of all records that I could find on the St. Lawrence near Massena, and from diligent search for information from the old inhabitants made by my assistants, I am led to believe that the obstruction due to ice upon the St. Lawrence, the Niagara, and particularly the St. Clair, is greater than I find allowed for in the yearly computations of flow reported in the annual report of the Chief of Engineers.

Q. Will you state the conditions which you have observed with reference to ice, upon the Mississippi, St. Lawrence, Niagara and St. Clair Rivers, with which you have personally been connected, and upon which you base the conclusion which you have just stated?

A. I have not my notes of field observations or of records of gage heights with me at the present time, and have trusted to my memory as to what I have seen of ice conditions and as to its effect upon the discharge of the rivers. But my recollections are very clear as to the immediate effect upon discharge produced by ice obstructions having been substantially as stated above.

Q. Will you describe the ice conditions which you have personally observed in these rivers that you have mentioned, the Mississippi, St. Lawrence and Niagara?

A. I have personally made more observations upon the St. Lawrence than on the other rivers; and have noted three or four different kinds of ice formation causing interference with the flow of the river.

The first of these is the ordinary smooth ice cover, which cuts off the section of water way at the top by a depth nearly equal to the thickness of the ice, and which causes a slightly increased friction upon the upper surface of the water, and thereby lessens the flow corresponding to a given gage height

in two ways: First, by the smaller cross section; and, second, by the greater friction against the water.

Q. Where did you observe this ice cover condition which you have mentioned?

A. I have observed this in a great many rivers, in the St. Lawrence, the Merrimac, the Mississippi and other rivers.

Q. And when?

A. From time to time during the past twenty years.

Q. How do you reach the conclusion that you have stated there, that there is an impediment to the flow caused by ice conditions?

A. This kind of obstruction is well recognized by all hydraulic engineers familiar with river flow, and is the simplest kind of obstruction from ice.

The second kind of troublesome ice, found more particularly on northern rivers, is the broken ice consisting of cakes which become detached from the ice cover at a point upstream, from a section of swiftly flowing water, and being carried by the current against the edge of an ice cover formed in the more quiet water at some section of broader area lying down stream from the open channel, are drawn beneath the surface of this ice in a way to gradually roughen the under surface of the ice and further increase the friction, as well as cut off an additional amount from the area of cross section of the waterway. The magnitude of this kind of obstruction is extremely capricious and uncertain, changing rapidly from day to day.

Q. Have you observed these conditions upon the St. Lawrence, Niagara and Mississippi Rivers?

A. I have, and on the Merrimack River also.

Q. During what period did they occur?

A. I may complete my previous answer by stating: As illustrating this rapidly changing condition, I would call attention to the measurements made upon the St. Clair River in January, 1901, reported on page 2835 of the report of Chief of Engineers for the year 1902, in which it will be noted that the discharge measured on January 15, was 181,200 second feet, while that measured on January 30, was only 97,000 second feet. On March 29, the measured discharge was 197,200 second feet; on April 2nd, 159,200 second feet. On April 5, this was found cut down to 108,500 second feet; and on April 10, to 74,000 second feet, which it will be noted was only about one-third of the quantity which was measured flowing on April 1st.

On April 12, the measured discharge was 86,900 second feet, and on the next day, April 13, was 128,700 second feet.

Again on April 16, the measured discharge was 178,300 second feet and on the 19th this was found cut down to 76,000 second feet, or but little more than one-third of the quantity measured three days previously.

In no other winter do I find that discharge measurements have been maintained during the ice season upon the St. Clair River or upon any of the other rivers which form the outlets of the Great Lakes, save a few on the St. Lawrence, which are given in much less detail.

On the St. Lawrence River, I now recall that my investigations showed that the outlet of Lake Ontario became frozen over with an ice cover that presumably was fairly smooth, but down the river at Ogdensburg, the ice cover was broken up for the purpose of maintaining communication between the railroads at Ogdensburg, on the American side, and Prescott, on the Canadian side; and the broken ice drifted down against the ice cover on the river below, under conditions which, from my experience elsewhere, I was led to believe might cause variable obstructions from gorging.

Further down stream on the St. Lawrence, before the Long Soo is reached ice troubles of a third kind begin. This third kind of troublesome ice is that sometimes called "anchor ice," but on these northern rivers near the Canadian border is called "frazil" ice. I have studied this ice during my efforts to keep the canal of the St. Lawrence Water Power Company in operation during the winter, and it has been studied in great detail by certain of the Canadian Government Engineers in relation to ice floods upon the St. Lawrence, which sometimes threaten various of the cities along the river, and result from the sudden clogging of the river by accumulations of this "frazil" ice, in combination with the broken cake ice, described as the second kind of troublesome ice above.

This frazil ice has also been carefully studied by Prof. Howard T. Barnes, of McGill University, Montreal, who has published a book entitled "Ice Formation," which in part deals with this matter.

A report of the Canadian Government investigations was published by Mr. Thomas C. Kieffer, Civil Engineer.

In my studies of the St. Lawrence conditions, I have had occasion to confer both with Mr. Kieffer and with Prof. Barnes; and Prof. Barnes has joined me personally in studying the conditions in the St. Lawrence near Massena.

This frazil ice chiefly forms on the bottom of the river, in the form of masses of needle-like crystals, which cohere in a mass so long as the temperature of the river water is a few thou-

sandths of a degree below 32 degrees Fahrenheit. This frazil ice forms on the bottom chiefly during the night, and becomes detached from the bottom during the slightly warmer temperature of the following day in great masses, which float down stream and gather beneath the ice cover and form hanging dams which greatly obstruct the flow.

During the past winter I have observed this frazil ice floating in the Niagara River between Chippewa and the intake of the Ontario Power Company, and coming down in such masses as to seriously obstruct the ice fender and in-take connected with the Water Power Works; and I have personally observed the men breaking this out from the openings by exploding dynamite, so as to admit a proper supply of water for the turbines.

From thus observing the frazil ice floating at Niagara, I am convinced from my studies elsewhere that this ice must have been formed upon the bottom of the river at some point in the rapids upstream; and I have no doubt that this formation upon the bottom of the river tends to cut off and reduce the flow over Niagara Falls, and therefore, to some extent, the magnitude of which I am unable to determine, holds back the outflow from Lake Erie and thus influences the height of the lake.

I note also on page 5360 of the Report of the Chief of Engineers for the year 1900, it is stated, with reference to the Niagara flow that: "In January, February and March, the decreased slope is doubtless due to the lodgment of ice in the lower river shallows above the rapids leading to the falls."

I have observed the formation of this anchor ice in rapids in the Merrimac River, and have pried large masses of it loose, while I have been making soundings for the building of a dam.

A fourth kind of troublesome ice is the so-called "slush" ice, which results from the drifting of snow into water, chilled to the freezing point so that it does not become melted, but partakes largely of the characteristics of frazil ice.

From carefully studying the reports of the Chief of Engineers for the past 12 years, in the light of my own investigations as to the obstruction of ice as above described, and from the general lack of reports concerning ice conditions, save during 1901 on the St. Clair, and a few observations on the St. Lawrence, I am led to believe that sufficient allowance for the retarding effect of ice upon the outflow from the Great Lakes

has not been made in the estimates by the Government Engineers.

Mr. Wilkerson: I submit that the statement of the witness does not disclose the basis for the opinion that the Government Engineers have not made sufficient allowance for ice obstruction, or for the conclusion as to the relative effect of the ice obstructions and the diversion of the water at Chicago.

Mr. Adcock: Q. Did you wish to say aynthing further upon the effect of ice conditions?

A. I desire to again call attention to "John R. Freeman Exhibit No. 1," to the diagrams plotted a little below the middle of the sheet and opposite the legend "Average monthly difference in elevations between Lakes Mich.-Huron and St. Clair," and also opposite the legend, "Average monthly difference in elevation between Lakes St. Clair and Erie."

These two diagrams were prepared from the diagram at the top of the sheet, by taking the differences month by month between the curves of the upper diagram lines for Huron and St. Clair, and these between St. Clair and Erie; and transferring these directly to the diagram below, thus mechanically performing the operation of subtraction.

The matter to which I would now call attention, in relation to the obstruction of flow of the St. Clair River by ice is, that not only in the year 1901, during the months of February, March and April is there an extreme difference of levels between the lakes, shown by a sharp peak extending upward on the Huron-St. Clair curve, and a sharp peak extending downward upon the St. Clair-Huron curve, which results from the obstruction by ice as described in the quotations and citations made above from the Report of the Chief of Engineers, but similar sharp peaks and depressions are found in many other years, notably in 1855, 1871, 1874, 1877, 1896, and many other years; and in some cases, notably in 1877, the disturbance of level is even greater than that found during the year 1901.

On the other hand, the diagrams now under examination show another class of ice effect in the year 1895, and 1909-10, in which the fall from St. Clair to Erie is about one foot greater than normal, and the fall from Huron to St. Clair about one foot less than normal; this indicating that the ice gorge at that time was in the Detroit River rather than in the St. Clair River.

Q. Are there any other fluctuations than those that you have heretofore described?

A. I have so far described only two kinds. There are at least four other kinds of fluctuation of lake level which tend to obscure the effect of the Chicago diversion, and make it impossible of direct measurement.

The third of these is the so-called seasonal rise, which results each year from the melting snows and spring floods, bringing an excess of inflow, which raises the level and gradually wastes away. It will be noted by an examination of the diagram, at the top of "J. R. F. Exhibit 1," that the lakes each commonly stand about one foot or more higher in the month of June than they do earlier in the year, or than they stand at the close of the season of drouth, towards the end of the year.

A fourth kind of oscillation is that which occurs from day to day, due to barometric changes, the effect of which appears to be very rapidly transmitted through the deeper of the Great Lakes.

A fifth disturbance or oscillation in the level of the lakes, some times greater in magnitude than any of the others, is that produced by long continued, strong winds blowing lengthwise of the lake. The observations of the government engineers show that the outlet of Huron is sometimes raised about two feet above its normal level because of such winds, and they also show that the easterly end of Lake Erie is some times tilted up six, or possibly eight feet above the western end after long continued strong winds.

And on page 24 of his report upon the Preservation of Niagara Falls (62nd Congress Senate Document 105), Mr. Shenehon states: "At Buffalo, in westerly gales, the water sometimes rises eight feet, and in easterly gales sometimes falls six feet, giving a range of fourteen feet." Also he states on the same page that there are three kinds of variations in surface level of Lake Erie at Buffalo: First, periodic variations in the lake stage, due to an accumulation of water from successive wet seasons, or the reverse due to a series of dry years. Thus, in 1895, the lake had a depth of 2½ feet less than it had in 1876. Second, seasonal variations due to greater water supply in the spring rains and freshets, resulting in the presence of more water in the lake in June than in November, by a foot or more. And third, the rise or fall at Buffalo," as just described.

He says also: "All three forms of variations may be superimposed, as for instance in the westerly blow in June, 1896."

The sixth kind of oscillation in lake level, which tends to

obscure precise measurement of such small changes as that due to the Chicago diversion, is the wave effect prevalent during high winds; these waves often rising and falling from three to five feet, or even more, at intervals of a few seconds. These rapidly changing oscillations may very seriously impair the accuracy of a gage reading from which the mean height is determined, if it is attempted to read directly from a graduated staff, or even with the standard type of floating gage used by the government, when the stilling device for this happens to be unskilfully applied.

I can find in the reports of the Chief of Engineers relative to the construction of these gages no proof that the precautions to secure accuracy during violent wave motion received proper attention.

Sources of error may come from the small inlet through which the pressure is transmitted happening to be so shaped that it is easier for water to flow inward than to flow outward, or vice versa. In my experience in water measurement, I have found this a common cause for lack of precision of measurement.

Another source of error in a floating gage enclosed within a "still box" may come from the orifice being placed in such relation to the current floating past that there is an addition or deduction from the true elevation caused inside the box, either by the impact or the suction of the current past the gage.

I find in some of the recent reports of the United States Engineers, notably that by Junior Engineer W. S. Richmond, dated June 15, 1912, relative to Hydraulics of the St. Lawrence River, which will be submitted in evidence and which has been furnished to defendant by complainant from the United States Lake Survey Office, statements that errors of this kind in gage heights near the head of the St. Clair River, which were used in the determination of the complainant's equation and increment of discharge, have recently been discovered.

The occasional violent and disturbing effects of these various kinds of oscillation are hidden in the tabulations presented in the Reports of the Chief of Engineers relative to lake levels, by reason of the fact that in substantially all cases the elevations therein recorded are averages of a great number of observations, and this process of averaging tends to smooth out and conceal the violence of the fluctuation of individual

readings of the gage. Thus, for example, the mean monthly heights appearing in the diagrams of lake levels published from year to year in the Report of the Chief of Engineers are each the average of from thirty to perhaps one hundred more or less discordant observations, in which the discrepancies tend to offset one another.

To illustrate the magnitude of the oscillations in lake level, and the rapid change of conditions affecting flow, which sometimes occur, I would call particular attention to Plate No. 1 in the Report of the Chief of Engineers for 1900, following page 5365, a photographic copy of which is submitted, and marked "J. R. F. Exhibit No. 2."

(Photographic copy of plate referred to was here marked "John R. Freeman Exhibit No. 2.")

From this diagram it will be noted that during a period of only about an hour and a quarter, from half past six A. M. to 7:45 A. M. on May 17, 1899, the government gage at the head of the St. Clair River showed a change in elevation of more than 2½ feet, or about ten times as great a change as that which it has been estimated would result from the diversion of 5,000 second feet at Chicago.

It will further be noted that the change in the discharge of the St. Clair River corresponding to the discharge curve used by Mr. Shenehon in computing the effect of the Chicago diversion, would vary from about 236,800 second feet to about 172,500 second feet, in the course of this period of about an hour and a quarter; which difference of 64,300 second feet is six times as great as the proposed 10,000 second feet diversion at Chicago.

It is not stated that oscillations so extreme as this occurred during the process of current meter measurement in the St. Clair River; but other diagrams and statements given in the published description of these gagings may be referred to as showing that during many of the measurements relied on for establishing the complainant's increment of discharge, there were oscillations of such magnitude as to seriously affect the precision of measurement of the discharge; particularly so when it is considered that the measurement of lake level used in the computations of discharge of Huron was made some sixty miles distant from the gage that was used during the current meter measurements for determining the elevation of the water surface.

Q. Would the probable error, which you mentioned there, be true in a computation of an increment derived from such observations, made under the conditions which you have mentioned?

A. There would be a lack of certainty, or lack of precision in an increment computed from observations during these changing conditions; and the fact that Mr. Williams in his computation of the increment excluded those observations during which there was evidence of a fluctuating condition in the lake is one of the reasons which leads me to regard his estimate of the effect of the Chicago diversion upon the lake level as being the more accurate.

Recess to 1:30 P. M.

After recess—1:30 P. M.

JOHN R. FREEMAN resumed the stand and testified further as follows:

Mr. Adcock: Q. Is there anything further you would like to say concerning ice effects, Mr. Freeman?

A. Only to make it plain that these ice effects have to do with the level of the lakes rather than with the determining of the increment or rate at which the discharge changes for one foot difference in elevation of surface, in the river or lake.

Q. You mentioned in answer to a previous question a change in the condition of the lake outlets due to scouring as among the reasons which prevented an accurate physical measurement of the effect of the diversion at Chicago. What can you say as to the magnitude of these changes, on account of scouring?

A. The record of the lake levels presented in the Annual Report of the Chief of Engineers indicates that a far greater change in the level of Lakes Huron and Michigan has been produced by other causes than that which it has been estimated would be produced by the diversion of 10,000 second feet at Chicago. And the most reasonable explanation which I am able to find for this change in lake levels is a deepening of the outlet of Lake Huron. That this deepening is a fact, and that it has been in part produced by natural scour and in part by the work of dredging a channel for the improvement of navigation, is indicated by various facts presented in the reports of the Chief of Engineers, and particularly in the report of the International Waterways Commission made in the year 1910, concerning the regulation of Lake Erie. Facts bearing on this condition are also stated in the report of the engineers on deep waterways, page 280, which states:

"Previous to 1886 the average fall from Lake Huron to Lake Erie was 9.2 feet, after which date the slope gradually diminished until 1890, since which time it has had an average of 8.3 feet. This decrease of slope was caused by the deepening of the river channels at the St. Clair Flats and at the Lime Kiln Crossing, by the Government; and by the great increase, from natural causes, in depth and cross section of the St. Clair River, through the rapids at the outlet of Lake Huron."

This report further states that:

"A survey made at the request of this Board in December, 1898, by a party under the direction of Lieut. Col. G. J. Leydecker, Corps of Engineers, U. S. A., shows that the gorge at the head of the river now has a central depth of 66 feet, and a cross section of 36,000 square feet; whereas, it had, at the date of the previous survey in 1867, a central depth of only 48 feet and a cross section of 30,000 square feet.

"While there are no records to show when the deepening of channels through the rapids occurred, a study of the water levels and the slope curves shown on Plate 83 indicates that erosion was probably started in the spring of 1886 by the abnormal fall (7.5 feet) of the St. Clair River, at that time." "It is probable that the decrease of 0.7 feet of the slope is due to changes in cross section through the rapids at the head of the river. And that the 0.2 feet change of slope in the Detroit River and St. Clair Flats is due to the increased depths of channels from Government improvements."

Plate No. 83 of the report quoted, of which a photographic copy "J. R. F. Exhibit No. 3" is presented herewith to be marked "John R. Freeman Exhibit 3," shows this condition in a striking manner.

(Photographic copy of Plate 83 was marked "John R. Freeman Exhibit No. 3.")

(Note: A more distinct copy of this diagram will be submitted in duplicate, to be substituted for the paper marked.)

I have not failed to note that this matter of scouring is also discussed upon page 5323 of the Report of the Chief of Engineers for the year 1900; and that reference is made to the preceding survey of 1859, which tended to dispute the correctness of the statement above quoted relative to the comparative measurement of cross section; but this does not dispute the remarkable change which has plainly occurred in the relative levels of Lake Huron and Lake Michigan with reference to Lake Erie. And it does not appear that the level of the bed of the river at the outlet of Lake Erie is equally susceptible to change, because the outlet of Erie is largely over limestone ledge, while that of Huron is over clay, and therefore susceptible to erosion.

I note also that this matter of scour is treated upon page 4115 of the Report of the Chief of Engineers for the year ending June 30, 1904; and in that report I find evidence that the engineers in charge appreciated the possibility of the change of levels being due to scouring at the outlet of Lake Huron, and in the St. Clair River.

It is of interest to note, while considering this matter of scour as a possible cause of the change in the relative levels of Huron and Erie, that there has apparently been a progressive decrease in the difference of level since the earliest records.

Table XII, page 4094, Report of Chief of Engineers for 1904 presents these data, and from these records it appears that the difference of level at times of earliest observations was about three feet greater than at present. In making these comparisons, I have selected those periods between June and November when the river must have been free from ice.

Some statements of great interest bearing on this matter are found in the Report of the Chief of Engineers for 1904, page 4115, et seq., wherein an extended comparison is made of the lake levels back to the earliest observation, and in course of which large discrepancies are noted between the discharge as computed from heights observed at the head of the St. Clair River, and those computed from the heights observed at the head of the Detroit River, which discharges must actually have been substantially the same; and the suggestion is made by the Government engineers: "In the discharge formula, an error may occur in two ways; either by the co-efficient, or in the datum of discharge."

"That there may have been such a change in the river is

possible, for the beds of the rivers are continually wearing away by erosion."

"The swift current in the narrow rapids from Fort Gratiot Lighthouse to the G. T. R. Gage is an especially favorable place for this kind of action."

"The bottom of the St. Clair River is subject to very great changes during ice blockades; the grounded ice plowing up the bottoms, and the concentrated currents at constricted places cutting away soft material very rapidly. When the ice blockade is lifted, it causes temporary steep slopes along the lower stretches of the river, with velocities of great cutting effect. After the great ice blockage of 1901, the swift current through the St. Clair Flats Canal caused a deepening of several feet at places in the lower end of the canal.

"The cutting of the river in the upper part where the current is strong tends to deepen it and increase the discharge. This is, in a measure, counteracted by the deposition of material in the slack currents of the channel and the shoal part of the flats, which tends to raise the bottom and diminish the discharge."

"In the shallow stretches of the river, the propeller wheels of steamers stir up the material of the bottom, which tends to deepen the channel and increase the discharge. From the head of Russell Island to the St. Clair Flats, a distance of 10½ miles, the depth of channel only exceeds by a few feet the draft of the largest steamers passing. In the last ten years, the draft of vessels passing has increased a good deal. The number of vessels, moreover, now passing, is greater than formerly. In the season of navigation, there are 33,000 vessel passages through Detroit and St. Clair Rivers. This may have had some effect in making the present discharge of river greater than it was in former years."

"The changes in the Detroit River are very likely to be in the same direction as in the St. Clair, but much less in amount."

Q. Omitting the consideration of the effect of natural scour, what would be the effect upon the levels of Lakes Huron and Michigan of the Government work in deepening the channel across the bar at the outlet of Lake Huron?

A. It is certain, beyond the shadow of a doubt, that this deepening of the channel by the government must have produced a lowering of Lakes Huron and Michigan. The earliest charts which I have examined, namely, that based on the survey of 1867, Plate VII of Williams' Exhibit 34, shows at that

time a bar obstructing the outlet of Lake Huron, across which the ship channel was only about 12 feet in depth. Since that time, particularly during the year 1894, 1895, 1896 and 1897, the government has increased the depth of the navigation channel at the outlet of Lake Huron to a depth no where less than about twenty feet.

I have represented graphically upon the diagram, "John R. Freeman Exhibit 1," the time and magnitude of the dredging in each of these years. This is shown near the center of the chart opposite the legend "Total annual dredging between Lakes Michigan and Huron and St. Clair except bar at head of St. Clair River."

The quantity of dredging in the several years is also stated in a table submitted by Mr. Williams, being Table LIII of Williams' Exhibit 34, which shows that the principal dredging at the outlet of the lake was during the three years 1894, 1895 and 1896.

Referring again to the diagram, "John R. Freeman Exhibit 1," and to the line plotted immediately beneath that showing the amount of dredging in the St. Clair River, under the heading, "Average monthly difference in elevation between Lakes Michigan, Huron and St. Clair," it will be seen by a careful comparison of that portion of the curve subsequent to 1896 with the preceding portion of the curve that there has been a very great lowering of the difference between Lake Huron and Lake St. Clair.

It is a matter of plain common sense, as well as of engineering experience, and certain beyond all doubt or question, that when a deep channel is thus dredged at the outlet of a lake into a steeply sloping river, that this providing of a deeper and larger gap in the rim of the basin through which the water can flow out, will, in the absence of building compensatory jetties or submerged dams along the outlet, have some effect upon lowering the average elevation of the lake, if conditions of rainfall and evaporation and inflow remain the same as before. And however difficult it may be to measure such a change in the level, amid the large and frequent fluctuations of the lake surface, it is certain that the providing of the deeper notch in the rim of the basin must result in lowering the elevation of the water in the basin, in some degree.

From examining the charts showing the depths of water at the outlet of Lake Huron, I find evidence that no compensation works have been built at this point which would block up the waterway to any degree sufficient to compensate for the

lowering caused by the dredging and deepening of the channel across the bar at the outlet of the lake. And considering the record of heights before and after this dredging, and considering also the area of the channel dredged, I have, as a matter of judgment and engineering experience, no doubt that the lake has been lowered as a result of this dredging to a greater extent than it has been lowered by the diversion through the Chicago Drainage Canal during the past ten years; or than it would be lowered by the proposed diversion of from 10,000 to 14,000 second feet.

Q. Suppose that the diversion of two, four, ten or 14,000 second feet at Chicago were to produce a lowering of the magnitude stated, namely, about five inches in the case of the 10,000 feet diversion of the Great Lakes, and in the same proportion as to the other amounts stated, could this be prevented? If so. how?

A. This could surely be prevented by building a series of jetties or wing dams at the outlet of each lake, or by one or more submerged dams (which might be composed of sunken cribs) sunk to a depth safely below the bottom of the boat of greatest draft; or being placed in such position as not to interfere with navigation. Such a remedy would in my judgment be complete, and would be comparatively inexpensive; and would prevent all of the injury that it is claimed would follow the diversion proposed at Chicago, by reason of shoaling of channels and harbors along the lakes and rivers connecting the same.

Q. Has this remedy of compensation at the outlet of lakes been tried out in any manner?

A. It has, in several cases, along the Great Lakes.

Q. How?

A. It has been tried and its sufficiency proved at the outlet of Lake Ontario by the Dominion Government, in building a dam across the Gut Channel, which formed a part of the waterway near the site of the Galops Rapids. These compensating works are known as the "Gut Dam." The probable effect of this dam was carefully considered by the United States Army Engineers prior to building. and the amount by which it would raise the water in the Galops Channel, and above, was computed, and it was afterwards found to be substantially correct; and statements to this effect are contained in the reports of the Chief of Engineers already cited. This

is referred to particularly by Mr. Shenehon, at page 479 of the record.

Q. Did this compensation, known as the Gut Dam, have any tendency to raise, or did it raise the level of Ontario?

A. It did raise the level of Ontario, and to an amount somewhat greater than that which it has been estimated Ontario would be lowered by the greatest proposed diversion at the Chicago Canal.

Q. Continuing your answer, do you wish to say anything further in answer to the previous question?

A. Yes. Another example of restoring, or rather raising the level of one of the Great Lakes by an obstruction built purposely at its outlet, is found in the outlet of Lake Superior, where, in order to increase the head for the Chandler-Dunbar Water Power Development, the head works appurtenant were extended between the piers of the International Bridge, so as to form a sort of wing dam, and diminish the natural outlet of Lake Superior. The effect of this obstruction can be seen in the diagram in John R. Freeman Exhibit 1 at the top of the sheet, in the increased level of Lake Superior in later years, as compared with the level of Lake Michigan. Its general effect was to raise the level of Lake Superior about six inches.

Another example of compensation works can be found at the outlet of Lake Erie, although these were designed more particularly for harbor improvement; and consist in part of the breakwater and other works built near Black Rock.

The fact of these works having had some effect on raising the level of the lake is referred to in the Report of the Chief of Engineers already stated.

A still more radical means for raising the level of Lake Erie, by means of an extended dam at its outlet, was presented in the report of the Board of Engineers on Deep-Waterways.

Mr. Alfred Noble, a witness in this case and a Member of the Board of Engineers on Deep Waterways, testified on page 31 of the record that the cost of such a dam was estimated at $796,923; but this was a far more elaborate structure than any that would be required to offset the diversion proposed through the Chicago Drainage Canal.

Q. Would such wing dams as you have mentioned, installed at the outlet of Lake Huron. interfere with navigation through the St. Clair and Detroit Rivers?

A. Not if they were properly designed, although it is pos-

sible that a single wing dam, or pair of wing dams from opposite shores built close to the outlet of the lake, might increase the abruptness of the fall at this point to an objectionable degree, this fall being already particularly steep and the current swift.

There is no necessity of doing the work in that manner, or in such a manner as to interfere with navigation.

On the other hand, this high slope immediately below the outlet of Huron could be lessened and all injurious currents avoided, by means of a series of wing dams, one pair being located down stream from another, so as to subdivide and distribute the fall over a considerable stretch of river, and reduce it to within limits such that the velocity would not be objectionable.

Q. Where would you place these jetties or wing dams that you mentioned?

A. At intervals within a mile or two down stream from the narrow outlet of the lake. It would require surveys and study on the ground as to the direction of present currents, and also of the depth and character of bottom before these could be located to the greatest possible advantage; but I have no doubt they could be so disposed as to thoroughly compensate for the small lowering of about five inches, which it is estimated would result from the maximum diversion at Chicago; and that they could be so placed as to make conditions of velocity and direction of current no worse than they are today. And on the other hand, I think it probable that an improvement might be effected by jetties or obstructions or compensatory works of this kind properly arranged.

Q. It has been suggested that the measure of damage to the navigation interests, that would be caused by the diversion of two, four, ten or 14,000 second feet through the Chicago Sanitary and Ship Canal, should be measured by the cost of deepening about six inches certain lake harbors and certain channels known as critical points of navigation. Do you consider that that would be a reasonable method of offsetting the effect of this diversion, or the reasonable measure of such damage?

Mr. Wilkerson: I suggest that is clearly a question of law.

A. As a matter of engineering, it is plain that compensation works could be built which would restore the lake levels to their condition prior to the Chicago diversion, or such as they would have in the absence of the Chicago diversion, at

only a fraction of the cost of deepening the harbors and channels to the extent of five or six inches.

Q. What would such works cost, Mr. Freeman?

A. I have not had time to visit the sites or to make the necessary surveys, or to prepare estimates, but plainly, as a matter of common sense as well as of engineering judgment, they would be very inexpensive. I can hardly imagine that works sufficient to restore the level, not only of Huron and Michigan, but also of Erie and Ontario, would altogether cost more than, say, one million dollars.

It would be a very simple matter to make the surveys and to estimate the cost of such works with precision. A structure of the kind needed, for compensation in levels sufficient to offset the estimated lowering of from four to six inches due to the Chicago diversion is of a very simple character, and may be of a class of work which costs comparatively little per cubic yard. No elaborate sluices or sluice gates are necessary for this purpose, and no operative mechanism, and no maintenance of a crew to supervise the working of mechanism or to maintain the works. Nothing is needed anything like so elaborate as the dam planned by the Deep Waterways Board of Engineers for the outlet of Lake Erie, which it is estimated would cost a little less than $800,000.

Q. The question of injury by reason of lowering the lake, say six inches and from drawing two, four, ten to 14,000 second feet through the Chicago Sanitary and Ship Canal has been raised. What can you say as to the certainty that any injury would follow such lowering of the lakes?

A. From my knowledge of conditions around the lakes, I believe it very far from certain that the net result would be injurious. On the contrary, there are many reasons for believing that such a lowering would be beneficial, in the sense that the benefits would much more than offset any possible injury, and would also be helpful to a much larger number of people.

I believe it highly probable that were the lakes in course of time thus lowered from four to six inches, there would be found no more real necessity or demand for restoring this level than has been thus far found for restoring, or compensating for the lowering which has already resulted from the channel improvements of the government by dredging through the bar at the outlet of Lake Huron; and the additional lowering that has followed natural scour at this place.

Q. What benefits do you refer to as coming from perma-

nent lowering of the lake levels of the amount that has been suggested?

A. When the Great Lakes, particularly Lakes Michigan and Huron, are at their high stage, such as they attain periodically at intervals of a few years, there is much difficulty in obtaining proper drainage of low lying lands near cities bordering the lakes, and difficulty in obtaining proper slope for drains and sewers, for discharging flood waters following heavy rains, into the lake.

This is particularly true south of Chicago; and I have a very distinct recollection of years ago seeing vast areas of ground near South Chicago practically awash at a time when the lakes were at one of their high stages.

A lowering of the high stage of the lakes by no more than six inches is of material advantage in giving a greater slope for the drainage of such lands.

Q. In your studies of the reports of the Engineers of the United States Army, or in your contact with the engineers engaged in the maintenance and improvement of navigation on the Great Lakes, have you seen or heard any suggestion of building compensation works at the outlet of Lake Huron to restore it to its proper level, or the level that it would have were it not for the cutting of the deeper outlet, as was done by the Government in order to improve navigation?

A. I have neither seen or heard it suggested to build works here to compensate for the lowering which has certainly been produced as a result of this excavation, supplemented by natural scour.

Q. From your examination of the Chicago Drainage Channel, known as the Chicago Sanitary and Ship Canal, connecting the Chicago River with the Desplaines River, what can you say as to whether the greater part of the cost of building this channel was incurred for purely Sanitary purposes, or for purposes of fitting it to become, at some future time, useful for navigation?

A. It is certain beyond all doubt or serious question that a channel over substantially the same route could have been built of sufficient capacity to carry 10,000 second feet or 14,000 second feet, which is the utmost that it is proposed to ever divert through this canal, for only a fraction of the cost that was necessitated in building a channel of the present dimensions, in order to fit it for navigation. Had the channel been built solely for sanitary purposes, that is, solely so as to give it a capacity to convey from 5,000 to 10,000 or 14,000 second

feet of water at the lowest levels of Lake Michigan, a cut probably less than 1/4 part of the width of the present cut would have served every purpose, for carrying 5,000 second feet considering that the slope of this channel from the Chicago River to Lockport could have been made at the steep rate of more than 1 foot per mile, and thus give a high velocity to the current.

It is certain that a much narrower channel than the present would have easily carried from 10,000 to 14,000 cubic feet of water per second, and that the amount of excavation would have been correspondingly reduced.

Although I have not had time to design such a channel, and compute its cost, it is my belief from general experience in the construction of large aqueducts and canals, that careful estimates would show that more than fifteen million dollars of the expenditure actually made upon the Chicago Sanitary and Ship Canal was distinctly for the benefit of navigation at some future time. And it is my belief that at some future time, whenever the contemplated works are completed through to the Mississippi River, this extra width and capacity obtained as a result of this expenditure will far outweigh any possible injury to navigation arising upon the Great Lakes or through connecting channels, from the lowering of their levels to the extent which has been estimated.

Q. You have stated that the estimates of the amount by which the various lakes might be lowered, as a result of diverting two, four, ten or 14,000 second feet at Chicago, are based upon certain gagings made at the outlets of the lakes, particularly Huron, Erie and Ontario, by the United States Army Engineers. Have you investigated these gaging records sufficiently to form some idea of their accuracy, and their stability as a basis for estimating the effect of the diversion of the number of feet indicated?

A. I have investigated these gagings from the very full description given in the various reports of the Chief of Engineers, and that given in the report upon the Preservation of Niagara Falls, and in the records previously submitted in this case.

Q. That is the exhibits?

A. The exhibits previously submitted in this case. These records are sufficiently complete to enable an engineer familiar with methods of river gaging and water measurements to readily comprehend the methods followed, and the precautions taken to insure accuracy.

Q. What are the results of those investigations that you have made?

A. I find that these gagings are on a larger scale, and made under greater natural difficulties than any previous river gagings of which I have knowledge, made anywhere in the world. And I find that the precautions taken to insure accuracy were most elaborate and painstaking.

I find that at first view, and so long as one studies the several gagings at one locality alone, and compares the agreement of the several observations made at this locality among themselves, they appear to be remarkably accurate, and their degree of precision and interagreement most excellent, considering the natural conditions. But when one goes further and compares the general result of the gagings made at Niagara with the general result of the gagings made at the outlet of Ontario, and the general results of the gagings made at the outlet of Lake Huron, and considers the quantity of water that must have come in from the tributary drainage area between these points of gaging; and also considers the limits of the evaporation which could have taken place from the area of these lakes in its relation to the rainfall upon the surface of the lake, the gagings at Niagara are strangely out of harmony and agreement with those on the St. Clair River and those upon the St. Lawrence River.

I find, moreover, from recent reports of United States Engineers connected with Lake Survey work that apparently in recent years serious questions have arisen as to the accuracy of these gagings by reason of comparisons of the nature of those that I have made between the outflow of Niagara, St. Clair and St. Lawrence rivers.

I refer particularly to the statements presented on page 4116 of the Report of the Chief of Engineers for the year ending June 30th, 1904, which states:

"A comparison of the outflow from Lake Erie through the Niagara River with the discharge of the St. Clair River for the ten years 1883 to 1892, June to November, shows that the computed discharge of the St. Clair River for that time is probably too large."

With reference to this discrepancy, my own investigations and comparisons would indicate that while the discrepancy is about as noted, it appears more probable that the error exists at the Niagara River than at the St. Clair.

On pages 4116 and 4117, a comparison of the discharge at Niagara with that through the St. Clair River is made, con-

fining the comparison to those months in which the rivers were certainly free from ice, namely, from June to November inclusive, and during the ten years from 1883 to 1892. This comparison leads to the strange result of showing that the discharge measurements give less water passing out of Lake Erie at Niagara than entered it at the upper end of the lake through the Detroit River, as shown by the St. Clair measurements plus a reasonable allowance for the drainage tributary to Lake St. Clair. And when further allowance is made in this comparison, to compensate for the effect of the lakes having averaged at a lower level at the end of each term than at its beginning, the comparison becomes still more strange in showing, if these discharge measurements at Niagara and St. Clair are to be trusted as accurate, that 18,000 cubic feet per second less water flowed out of Lake Erie all through this period than the amount that was measured into it through the St. Clair and Detroit Rivers.

It is obvious, and certain beyond serious question, from general engineering experience in the yield of watersheds, and from many experiments upon the evaporation of water surfaces that, on the contrary, there must have been a distinct increase in the quantity of water flowing out at Niagara over that flowing in through the Detroit River, due to the contribution of the watershed directly tributary to Lake Erie during these months from June 1st to November 30th.

The land drainage directly tributary to Lake Erie, apart from the lake surface, is about 25,000 square miles; and the net yield from this during these months from June 1st to November 30th, if proportional to that of the entire drainage area of the Great Lakes, would be not far from 30,000 cubic feet per second.

From a computation of this kind, Assistant Engineer Thomas Russell estimates (see page 4117 Report of Chief of Engineers for 1904), that to grant the accuracy of the discharge measurements at both Niagara and the St. Clair Rivers involves the supposition of an evaporation from the surface of Lake Erie averaging about 48,000 cubic feet per second for the six months, or 32 inches in depth, which, he says is "an amount which seems too great."

In my opinion this amount is so absurdly large, and so contrary to all engineering experience upon the run-off of watersheds in this region, and the evaporation from water surfaces under similar conditions as to prove that one or the other of these sets of gagings, either those on the St.

Clair River or those on the Niagara River, involve some serious and as yet undiscovered constant source of error.

Although doubtless there is much evaporation from the broad surface of the lake itself, it must be remembered that the lake also receives the full depth of rainfall, from June 1st to December 1st, by way of compensation for evaporation. And that the most accurate measures of evaporation and run-off of water which we possess would lead us to expect that this rainfall upon the lake surface during these months would pretty nearly balance the evaporation, when one takes account of the result of such observations as those made in connection with the Salton Sea in southern California, which showed that evaporation from a broad lake surface far from the shore is materially smaller than that from a small tank on the margin of the lake.

Some experiments made by the Water Department of the City of Rochester, within about ten miles of the margin of Lake Ontario, and covering a period of twenty years, which are being copied preparatory to introduction as an exhibit in this case, show a decidedly less quantity of evaporation from a tank in the midst of the reservoir than from a similar tank upon the shore.

My reason for thinking that this error more probably exists in the Niagara discharge measurements than in those on the St. Clair River is that upon making a similar comparison between the Niagara discharge measurements and the discharge measurements on the St. Lawrence River, both made principally by Mr. Shenehon, there is a similar discrepancy, but in the opposite direction, when one takes account of the probable run-off from the watershed tributary to Lake Ontario and the probable evaporation from its surface.

In other words, the St. Clair gagings and the St. Lawrence gagings are found to agree as well as one could expect, when taking account of the probable inflow from the watershed between these lakes, and the amount of evaporation from the lake surfaces, while the measurements on the Niagara River are, roughly speaking, some 30,000 second feet smaller than we should expect to find them, from a comparison with either the St. Clair gagings or the St. Lawrence gaging.

Q. Where do the Salton Sea observations appear, Mr. Freeman?

A. I have personally seen their apparatus, when I have been travelling through the region; and I think the experiments have been reported in some of the current engineering

publications; but they are given in abstract in one of the latest and most popular engineering handbooks, the "American Civil Engineer's Pocket Book," which shows in general, as I remember it, that the evaporation over an extended water surface will be not over from two-thirds to three-fourths that from a small tank on the shore.

Q. Over what period of time did these observations extend, if you know?

A. During only a few years past, possibly four years; but the observations on the tank at Rochester, in comparison with a similar evaporation tank on the shore of the reservoir have extended over some twenty years; and that has the advantage of being in proximity to one of the Great Lakes.

Q. Do you know anything about the care with which those observations were made?

A. I do not personally, except I have every reason to believe they were made with a very high degree of accuracy. They were made under government supervision and for a distinct purpose of estimating the length of time that it would probably take to restore the original condition from the evaporation of the water that came into the Salton Sea through the break in the Colorado River.

Q. Those observations are considered as authentic by the engineering profession?

A. I believe they are. Yes, they have been so accepted.

Q. And with reference to the observations made by the Water Department of the City of Rochester, do you know anything about the care with which those were made?

A. I am personally acquainted with the former city engineer of Rochester, under whose care they were begun, and with the present city engineer of Rochester, under whose supervision they are maintained. I know that both are engineers of very high standing and any of their data are entitled to the highest degree of confidence.

Q. In your experience in measuring flowing water by means of current meters, have you found any difficulties that might lead to error of the kind that you have mentioned? If so, will you state what the difficulties are?

A. I had an experience about seven years ago, in making measurements in connection with a turbine test in some of the tail races of the water power plant of the St. Lawrence River Power Company, at Massena, New York, in which I found, to my great surprise, difficulties of a kind which I think offer the most probable explanation of the discrepancy in the meas-

urements at Niagara, as compared with those at St. Clair and St. Lawrence.

In the case of these gagings at Massena, I had, in the effort to obtain accurate measurements, had so-called "stilling racks" inserted at the head of the race-way, in order to quiet the eddies and general turmoil in the currents of water approaching the current meter; and the water was apparently satisfactorily quiet upon the surface, and suitable for presenting an opportunity for accurate measurement. But my suspicions were aroused because the results, in relation to the efficiency of the turbine, did not appear reasonable, and also they did not agree with some other measurements by current meter which I had made in the relatively quiet water of the canal, up stream from the power house. And this led to a very careful investigation of the conditions at the bottom of the tail race, which was some 12 or 15 feet in depth; and by devising a sort of inverted weather vane consisting of a rudder firmly attached to a long pole, which I could immerse to the bottom of the race-way, while the upper part was held in my hands or the hands of my assistant, I was able to detect a condition of far more violent agitation and eddying at the bottom of the race-way than that which appeared on the surface. And thereupon I introduced additional stilling racks at the head of the race-way, until I had gotten the currents into a substantially parallel condition from top to bottom, as judged by the feeling and tests with my inverted weather vane or rudder; and after that we obtained measurements with a current meter which did appear reasonable and satisfactory, and which I gave full credence to.

This matter of the impairment of the accuracy of current meter gagings by disturbed conditions of the current has been one that did not receive particular attention among engineers until quite recently. But it has been somewhat investigated of late by several engineers, though by no means as completely as I believe its importance deserves.

The most recent observations on this subject with which I am familiar are those made also at Massena in connection with some other turbine tests by Mr. B. F. Groat, who was formerly one of my assistants, and who had reported his experiences in the Transactions of the American Society of Civil Engineers for December, 1912.

Mr. Groat finds as a result of his experiments, which I believe are by no means so complete as desirable, that the Haskell meter, which was the type used in all of the gagings at

the outlets of the Great Lakes was affected by disturbed currents very much less than the Price meter, which was the type that I had used at Massena. But nevertheless, he concludes that the Haskell meter under extreme conditions of disturbed currents "will under register by not more than three or four per cent." (See pages 60, 63, Proceedings Am. Soc. C. E. Dec. 1912.)

Mr. Adcock: I submit the report referred to for identification, to be marked "John R. Freeman's Exhibit 4"; to be identified, and such parts to be used as required.

(Report referred to was marked "John R. Freeman's Exhibit 4.")

Mr. Wilkerson: I reserve the right to object to the testimony with reference to the contents of this report of Mr. Groat until I have examined the document. It may be that he should be called, and it may be we will not deem it necessary. We will leave that point open until we have examined the report.

Mr. Adcock: Q. I will ask you if you know Mr. Groat, and if you know anything about the care with which he carried on the experiments which have been made?

A. Mr. Groat was formerly an assistant professor of the University of Minnesota, and I found him a very painstaking, careful observer. I should say that I do not consider that in this particular study he goes thoroughly to the bottom of this question, or that he experimented on conditions which were so extreme as may possibly exist in the Niagara River, at the point where gaged by Mr. Shenehon. But I submit this has shown the discrepancies or errors liable to be introduced in current meter work, where the meters are rated solely in still water, as they were in the case of the work on all of these discharge measurements for the Great Lakes.

I would also call attention to the fact that so far as Mr. Groat's observations go, they are favorable to the superior accuracy of the type of meter used in these gagings, as compared with other popular types of meters.

I am somewhat familiar with the Niagara River, and have noted the appearance of its surface as seen from the shore at many points between Lake Erie and the head of the falls. And it is my belief from what I have seen and can remember relative to conditions down stream from the International Bridge; and also from the statements and descriptions presented in Mr. Shenehon's report of his work, that the discrepancy above noted in the Niagara gagings most probably re-

sults from a condition of violent agitation in the flow of water, at the depth of 20, 30 or 40 feet beneath the surface, and which may be vastly more violent than indicated by the appearances of the surface.

Mr. Shenehon describes the conditions on page 5328 of the report for 1900 of the Chief of Engineers U. S. A. as follows:

"The Niagara River as it breaks out of Lake Erie flows almost due north. It narrows rapidly, and passes swiftly through a choked section of limestone where the speed at midriver must approximate 8 miles an hour. On emerging from this, the river grows wider and deeper and slows up to about 5 miles an hour as it approaches the International Railway Bridge 12,000 feet below the head of the river. In this distance, the fall is about 5 feet at mean lake stage."

This fall of 5 feet in a distance of about two miles and a half is an extremely rapid fall, and indicates that the energy and velocity naturally appurtenant to so great a fall in so short a distance must have been expended chiefly in the violent internal friction of the eddying current.

From observations which I have made at the outlet of other lakes, and from photographs which I have seen of the bed of the Niagara River upstream from the falls, exhibiting the roughness of the bottom as revealed at the time it was unwatered, I think it highly probable that the bed of the river at this point may have been roughened and made ragged by boulders and fragments of ledge that have been dropped by the ice.

Mr. Shenehon refers to these conditions in the following words: at the section where the first season's gagings were made, namely, directly beneath the International Bridge, he says, "The piers rest in timber caissons, and are provided with cut-waters. Protective masses of large stone are dumped about the piers, making a somewhat ragged profile and a bottom dangerous to instruments."

It is also of interest to note from the drawings of the cross section presented that at one point it is still further roughened and obstructed by a large sunken crib. These conditions are shown on Plate VI following page 5360, Report of Chief of Engineers for the year 1900. Mr. Shenehon says on page 5342 of the Report of Chief of Engineers for 1900:

"In such a section as that of the International Bridge, the proper derivation of the velocity coefficients is the most difficult part of the river gaging. To obtain it, the writhing mass

of water streaming through the bridge openings and eddying about the piers, spurting and lagging in minor pulsations, speeding faster as the lake rises, and flowing leisurely in the low stages, must be congealed to a solid by some instantaneous method of survey and its dimensions taken."

It is my belief that because of this writhing and eddying of the liquid filaments deeply beneath the bed of the river that conditions were introduced to which even a meter of the excellent Haskell type did not properly respond. And I know of no experiments made anywhere which would indicate the error introduced by such conditions. The work of Messrs. Haskell and Shenehon in gaging the Niagara River under these exceptionally difficult conditions was pioneer work, and I know of no previous experiences that would have led one to expect that so great an error could exist as that which is made evident by comparison with the gagings in the more quiet waters of the St. Clair and St. Lawrence.

On general principles, one would expect the mechanism of a current meter of the Haskell type to under register rather than over register, under conditions of violent agitation and twisting of the fluid filaments. These conditions as I conceive they may exist at the bottom of the Niagara River are very different from those presented by an ordinary eddy where a great body of water moves more or less in a circle, and with comparative quiet and uniformity of direction among the neighboring filaments. And from my experiments in water measurement, I consider it quite possible that the conditions found within such turbulent and violently agitated currents as may exist near the bottom of the Niagara River may produce very different effects upon a current meter from those that are artificially produced in tests when the meter is suspended excentrically from a moving boat and the boat rocked in order to give a changing direction to the meter in its progress through the water.

It is stated in one of the reports of the Government engineers that the still water rating of these Haskell meters had been confirmed by direct observation of the velocity of the water in the river, by timing a ball of colored water over a measured course. These tests are already in evidence in this case.

While I accept the accuracy of this particular test, I do not think it represents any such conditions of agitation or twisting of the fluid filaments as those likely to prevail at great

depths when a river bed is strewn with large fragments of rock or with boulders that have been dropped by the ice.

Q. What have you noticed in general as to the disturbed conditions of flow near the bottom of the outlets of the lakes mentioned?

A. My observations, so far as the outlets of the Great Lakes system is concerned, are confined to the St. Lawrence River, and more particularly the portion of this up stream and down stream from the Long Soo. Here I have personally noted, when making soundings in the river, the presence very generally of a boulder strewn bottom, which I judged to have been largely caused by the transportation of boulders imbedded in the ice, and which were dropped along the river when the ice lost its grip upon the stones.

I have observed similar conditions elsewhere, for example near the outlets of certain lakes in Maine; and I am inclined to believe it a common condition along the outlets of lakes and along the shores of large rivers in a glacial formation, where boulders prevail. Therefore I think it highly probable that near the outlet of Ontario, and also at some of these other gaging stations, the bottom may be so strewn with boulders and cobble stones as to lead to an exceptionally large disturbance of the currents, and one which may seriously interfere with accurate measurement by a meter whose rating depends upon a test in still water.

The "boils" which one often sees in deep and swiftly flowing channels, where there is a fairly smooth surface, are probably each the result of the deflection of the current by a boulder on the bed of the river at some little distance up stream. Here at the site of the Niagara measurements, particularly at the section at the International Bridge, and also in the open section about 1800 feet down stream therefrom are I believe more likely to present particularly rough bottoms than are the sections at St. Clair and along the St. Lawrence.

I have judged this from the statement as to the river flowing over a broken limestone ledge a short distance upstream, and from the extremely rough and disturbed condition of the bed of the river upstream from the Canadian Falls, which was revealed when a large area was unwatered in connection with building the intake to the power works.

As to other sources of error, commonly found in current meter gagings, some relatively small errors may have, I think, been introduced by the variable condition of slope and by the pulsations of height of lake which occur near its outlet, but

these among so many independent discharge measurements would tend to balance and offset one another; and in explaining the discrepancy of the Niagara gagings as a whole, one must seek for one or more sources of constant error of far greater magnitude than the errors found between these individual observations.

Q. In that last statement you referred to the gagings on the Niagara, did you not?

A. Yes, to the gagings on the Niagara.

Q. How great do you find the divergences between separate discharge measurements, in comparison with the quantity of water now diverted and proposed to be diverted through the Chicago Sanitary and Ship Canal?

A. All through the many individual measurements at Niagara and St. Clair and upon the St. Lawrence, there are differences between successive measurements at the same stage of water, which are greater than the quantity now diverted through the Chicago Drainage Canal; and the greatest quantity which it is proposed to divert at Chicago will be smaller than the range of error or discrepancy between observations taken at the same mean depth at each of these gaging stations.

For example, at the two Niagara gaging stations, successive measurements on the same day when the quantity flowing must actually have been nearly the same, showed differences, on October 11, 1899, of 15,650 second feet; upon November 1st, of 11,320 second feet; upon November 26th, of 8,420 second feet; upon November 7th, of 11,900 second feet; on December 10, of 9,640 second feet, the above measurements all having been made at the Bridge Section in the year 1898.

At the Open Niagara Station, which was considered more favorable, being less subject to the disturbance of the bridge piers, I note among the series of measurements made in the year 1899 there were similar discrepancies between successive measurements upon the same day. For example, on October 7, the two measurements differed by 8,700 second feet; on October 12, the two measurements differed by 8,810 second feet; on October 28, the second measurement differed from the first by 14,130 second feet; on October 31, the difference between the two was 10,320 second feet; on November 3rd, the difference between the two was 10,520 second feet; on November 11, the difference was 7,280 second feet, and on December 6 the difference of the second measurement from the first was 9,400 second feet. These discrepancies, although many of them are larger than the proposed 10,000 second feet

diversion at Chicago, are not particularly large as such measurements commonly result in hydraulic experience upon quantities of this magnitude. But they serve to illustrate and justify my answer to your earlier question that it would be impossible to directly measure the amount of the Chicago diversion by any direct physical measurement.

Q. How does the quantity which it is proposed to divert at Chicago compare with the probable error in the best measurements that have yet been made at Niagara?

A. A diversion of 10,000 second feet would be only about 5 per cent. of the apparent flow at Niagara, St. Clair or the St. Lawrence. but judging by the long series of gagings upon the St. Clair and those upon the St. Lawrence, these Niagara measurements as a whole are probably some 20,000 to 30,000 second feet too small, or probably the final error resulting from the average of all of these very elaborate measurements at Niagara extending over several years is more than twice as large as the magnitude of the proposed diversion at Chicago.

Q. Passing now, Mr. Freeman, from the question of error in the measurements at Niagara to that of possible errors incident to the method followed on the St. Clair River for determining the delivery from Lake Huron by means of the daily records kept for many years at Harbor Beach, are there possibilities of constant errors in these gagings?

A. There are.

Q. State just what your conclusions are?

A. In the first place, no simultaneous, frequent observations of the gage height at Harbor Beach were used in a direct comparison with the discharge measurements in the St. Clair River; but these two separate pieces of data were brought together subsequently by means of an independent series of comparisons of the gage of Harbor Beach with the gage at the section where the discharge was measured; and the later investigations by the government engineers, as set forth in the report of Junior Engineer Richmond made in June, 1910, already referred to, appear to have established that some serious errors were made originally when working out this relation. Granting this relation to have been established with accuracy, there are uncertainties due to the changing slope of the river past the gaging station, which changing slope is induced by the changing elevation of Lake Huron under the influence of wind, which has already been illustrated by the diagram introduced, John R. Freeman Exhibit 2.

The character of these changes, and their magnitude, is

shown by the following diagrams which are photographic copies of Plates VI, VII, VIII, IX and X, which show the result of observations made in course of the careful study of conditions of changing slope and velocity made by the engineers in charge of the measurements of the St. Clair River.

Mr. Adcock: I submit for identification the Plates above mentioned and ask that they be marked "John R. Freeman Exhibit 5 to 9" inclusive, in the order in which they were described by Mr. Freeman. They appear in the Report of the Chief of Engineers for 1900 following page 5400, being indicated there in the manner in which Mr. Freeman has stated in describing them.

I consider that the care taken to record these conditions and to prepare these diagrams tends to prove that these measurements were of the most painstaking character, and, as already stated I believe they are superior in care and precautions to obtain accuracy to any river gagings that have ever yet been made elsewhere. Nevertheless, the discrepancies between individual observations that occurred in spite of all these precautions serve to illustrate the difficulty of measuring or detecting quantities of 2½ per cent. or 5½ per cent. in volume flowing, which correspond to the diversion present and prospective through the Chicago Drainage Canal.

While these pulsations tend to offset one another in the course of the great number of observations made on the St. Clair, the Niagara and the St. Lawrence, and thus become smoothed out, not only in the final result but also in the individual discharge measurements, there are possibilities of other errors of a constant nature such as that of a changing position of the thread of the current under varying slopes, and stages of the river, and I do not find that this particular matter was investigated so thoroughly as would appear desirable.

Q. You have had experience, I believe you stated a little while ago, Mr. Freeman, in connection with providing water supply for cities in the United States?

A. I have, for Boston, New York, Baltimore, Los Angeles, San Francisco and elsewhere.

Q. Do you consider it necessary to keep that water supply free from the contamination by raw sewage or any effluent that might be discharged there after a purification?

A. It is in the highest degree important to do so. It is a condition almost paramount to all other conditions as affecting the health and prosperity of the commodity.

Direct examination closed.

Adjourned subject to notice.

October 13, 1913, 2:00 P. M.

Met pursuant to adjournment.

Present same as before.

JOHN R. FREEMAN, resumed the stand and testified further as follows:

Cross-Examination by Mr. Wilkerson.

Q. In comparing the two methods which were used by Mr. Williams and by the Government Engineers, in dealing with the discharge measurements in this case, you pointed out as a difference that Mr. Williams had used a method which was known as the three point method; and you gave that as one of the reasons why the results obtained by Mr. Williams were more accurate than those of the Government Engineers. At the time you made that comparison did you know as a matter of fact that the formula which had been presented by the Government had been checked by the method of least squares?

A. I did not.

Q. As an engineer, what do you say as to the relative value of the method of least squares and the three point method, in dealing with observations of this character?

A. As a matter of practice, I have very seldom used the method of least squares. I have commonly found it sufficiently accurate to stretch a string and get my mean in that way, just as I assume the curve presented by the Government Engineers has been derived.

As between the least square method and the three point method, my present impression is this: That the three point method is simpler of application. As to the bearing of the theory of probabilities on the two methods, the three point

method and the least squares method, I would not be ready to express an opinion at the present time. I regard the three point method as a more ready method of application, and sufficiently good.

Q. But as to which one would give the more accurate results, you would not be prepared to express an opinion without further study?

A. No, it is largely hypothetical.

Q. Well how much difference did you think resulted, growing out of the fact that a string had been stretched rather than the figures handled according to the three point method?

A. That was shown on the diagrams presented by Mr. Williams. The difference was not large. I could not attempt now to say just what that difference was.

Q. The error, if any, which would come from the simpler method of drawing a string would be just as likely to fall on one side as on the other, would it not?

A. My recollection is that in this case it was plainly seen that as they had drawn the tread, or as they had drawn the line, it tended to magnify the effect of any diversion in lowering the lakes.

Q. That is that one thing alone did that?

A. Its tendency was in that direction.

Q. Why would its tendency be in that direction rather than in any other direction?

A. I would say I am trusting now to the memory of curves I have not looked at for six months, and I think it would be safer for me to turn back to those particular diagrams.

Mr. Adcock: We can get those to refresh his recollection.

Mr. Wilkerson: I can simplify this.

Q. Did you see this chart which was presented to Mr. Williams in New York?

A. I did; I examined it carefully.

Q. In which the observations of the Niagara discharge were plotted?

A. I did.

Q. And the line was drawn through those observations by him?

A. I did see it.

Mr. Williams: It is a chart that Mr. Freeman has not seen. I have a copy of that in my files, and Mr. Freeman has not seen it. He has in mind now other charts, Exhibits 1, 2, 3 and 4.

Mr. Wilkerson: Q. I am referring to a chart which I sub-

mitted to Mr. Williams, in connection with his cross-examination in New York.

A. No, I have not seen that.

Q. I will show that to you.

A. I was trying to recall my recollections of a chart which Mr. Williams did give me in which he had drawn observations, and to which I had applied the two methods.

Q. As a matter of fact, when did you first come in contact with this three point method of handling the observations?

A. My impression is I have known of it in a general way for quite a long time, but that I have not used it practically.

Q. Have you ever come in contact with a piece of work in which it has been used until this case?

A. I can't say positively. I think so.

Q. Do you remember any specific piece of work?

A. I do not.

Q. You have come in contact, have you not, with discussions of observations in which the method of least squares was used?

A. I have, frequently.

Q. Frequently. And you have used that yourself?

A. Very rarely.

Q. But when you wanted a result deduced by a more accurate method than the mere drawing of the thread, you have used the method of least squares, isn't that true?

A. Very rarely, but I will say that I have generally been content with drawing a thread.

Q. When you have used anything else, it has been the method of least squares?

A. Not always. I think I have used a method of moments, somewhat similar to this three point method, but very rarely.

Q. How does the method of moments which you have used differ from the method Mr. Williams used?

A. I can't recall now that it differs at all. I have used either the three point method or the method of least squares very rarely, hardly once in a dozen years I may say.

Q. Isn't it a fact that those who have to do with a series of observations, and who wish to deduce very accurate results from them have as a general rule used the method of least squares?

A. I believe they have. And I will say that the method of least squares—that the superior accuracy of the method of least squares is mainly a very abstruse theoretical matter, so much so that it is seldom used outside of astronomical observations, or outside of some of the refinements of the United

States Engineers, as for example in reducing geodetic determinations. I think it is very rarely used in practical hydraulics.

Q. You know as a matter of fact that it was used by the Government Engineers in connection with some of these very computations, do you not?

A. I have an impression it was. I think I have seen pages of their deductions, in some of their reports.

Q. Now you said the first reason for giving a greater degree of inaccuracy to the Government Engineers than to Mr. Williams was the failure of the Government Engineers to use the three point method. Another reason which you assigned was, as I recall your testimony, that the Government Engineers in preparing their discharge curve had used all of the measurements of discharge, while Mr. Williams in his studies of these observations had selected out of the great number of discharge measurements certain discharge measurements, and had reached his conclusion from these selected observations. Did you make a study of the entire series of observations, and of the observation which Mr. Williams had selected, for the purpose of determining the plan which Mr. Williams had followed in his selection of observations?

A. I reviewed the entire series as published to an extent which I believe justified me in drawing that conclusion that there were observations which plainly were less accurate than some other observations taken at periods of disturbance when the flow was not constant. And I satisfied myself that Mr. Williams had excluded a large number of those observations taken under the least favorable conditions. I cannot say that he had excluded every one.

Q. Do you remember what percentage of the observations taken on the St. Clair River he discarded?

A. I do not. My impression is it was quite a considerable proportion.

Q. Was it more than half of them?

A. At present I should not think it was.

Q. Do you remember how many of the observations on the Niagara were discarded?

A. No, I do not recollect the proportion. Six months ago I could have told you.

Q. Did you know that he had included observations made during the winter season, during February, in the study which he had made of the Niagara observations?

A. No, I do not recall that. In a warm February, he might

be justified possibly in including such observations, if the conditions were steady.

Q. You know as a matter of fact there were observations used in February, when there was ice?

A. No, I did not know that.

Q. Did you know that he had omitted entirely 118 of the Niagara observations for the years 1907 and 1908?

A. No. If I ever knew it, I have forgotten it. I have no present recollection of it.

Q. All I am trying to get at is, when you made your study of Mr. Williams' computations, did you detect those facts to which I have directed your attention?

A. No, I presumed that he had used everything available.

Q. You did not check them against the original series of observations?

A. No, I stated so in my testimony.

Q. Now how did you understand he had treated these observations, with reference to referring a group of observations or the average of the group to a particular gage reading; that is to say, to make myself clear, did you understand that he had gone back to a gage reading which was prior, in point of time, to the discharge measurement?

A. I did understand that, yes.

Q. How did you understand he treated that?

A. I understood that he had gone back to an amount sufficient to allow for the period of transmission of the condition from the point above down to the place where the measurement was taken.

Q. How long a period did you understand that was, how many hours?

A. I don't recall at present, but several hours as I remember it.

Q. Was it 24 hours or 12 hours?

A. My impression is that as an average it could not have been more than 12 hours. I know there was an allowance of that kind.

Q. Now suppose, Mr. Freeman, in comparing two sets of observations for the purpose of deriving an increment, the observations were so selected, and this antedating of the reading of the gage was so manipulated that for very high discharge measurements, the effect of that method would be to refer them to a low gage reading; that is to say the lake rising, while for very low discharge measurements the effect of that would be to refer them to a high gage reading, the lake falling, so that there would be a smaller difference in gage reading

corresponding to a greater difference in gage reading. The effect of that would be to give a larger increment than would be derived if the observations were combined in the ordinary method, would it not?

A. If there had been many cases of that extreme character, but naturally one condition would offset another so that there would be a compensating effect.

Q. Naturally you would expect the groups to fall, so that the difference in one case would be offset by a corresponding difference the other way, in another case. But it would be possible to select the groups in such a way as to get a larger increment by that method?

A. That might be done.

Q. And that illustrates, does it not, the danger of deducing a conclusion from selected observations rather than from—

A. Not necessarily, if one is honestly seeking the truth.

Q. But if one is earnestly seeking to establish a large increment, the fact that the lake is rising and falling, and that groups of observations can be referred to gage readings in that way would furnish a method whereby a larger increment could be derived, if one wanted to do it, wouldn't it?

A. That is conceivable in a general case, but not in this particular case.

Q. You say it is conceivable, in a general case?

A. Yes.

Q. But not in this particular case?

A. I believe it is not.

Q. By that do I understand you to say you have studied these groups of observations?

A. I did in a limited way, yes; spent several hours going over them.

Q. To show you what I mean by that, I direct your attention to Exhibit L for Identification October 8, 1913, Sheet number 3 (handing same to witness), and also to Table XLVa, group 12. On this chart here, the observations 91, 92, 93, 94, 95, 96, are plotted there?

A. Yes.

Q. And the group is averaged?

A. Yes.

Q. That would give the average observation which is used for that particular group. Now, that is referred to a particular gage reading. As I understand, instead of referring it to the actual gage reading, the gage reading is shoved back so as to include the day before. If you took that group for

example, the effect of that would be to refer the average of the discharge observations to a lower average gage reading than would have been the case if the observations had been referred to the gage readings corresponding to the time of the observation, would it not?

A. After studying the diagram, and without attempting to follow through all of the successive steps, I can see that in this particular case by including the mean of the entire preceding day, the result was over-corrected; that is the attempt to compensate for the period required for the condition prevailing at the lake to pass down to the gaging station was over-compensated, and since the preceding day happened to be a day of lower height than the average of the whole period, the effect was to introduce a small error.

Q. That is the effect was to refer the average of the discharge measurements to an average gage reading which was lower than it would have been if that day had not been included?

A. To a very small extent, yes.

Q. And of course it appears in this particular case that the observations were selected in that way, grouped in that way?

A. As I understand it, the same method was followed in every case. And I think that in the absence of fuller information, the attempted correction was in the right direction. It may have been somewhat overdone, but I think taking a long series of many observations you would probably find just as many days when the preceding day was a little higher than the average as you would days when it was lower than the average, as in this particular case.

Q. That would depend entirely, however, on how the observations had been grouped?

A. No, because the same rule was applied all the way through of including the day previous as a means of compensating for the time taken for an effect to pass down the stream from the lake into the channel at the gaging station.

Q. You notice there do you not, Mr. Freeman that in this particular group of observations on the 29th of June, while there is an apparently wide fluctuation in lake elevation, the discharge measurements as plotted appear to be substantially on the line corresponding to the lake elevation, do they not?

A. I find they appear so in that case.

Q. And that is true in a large number of cases is it not?

A. I find that in general the observations follow the line of height very well indeed; that there are occasional divergencies of 5,000 or 7,000 cubic feet per second, but in general they follow the line very closely.

Q. Now, in the light of that, are you prepared to say that observations are to be rejected, because there happens to be on a particular day a greater fluctuation of lake elevation than the ordinary?

A. This is the first time I have had an opportunity to examine these (Referring to charts produced by Government's counsel).

Q. They have all been marked for identification, and they were before Mr. Williams in connection with his cross-examination?

A. I would say that from examining these curves, I do not find that the periods of rapid change in elevation of the lake are those in which there is any particularly large divergence of the observation from the continuous hourly curve. But at the time I was considering this matter six months ago, I did not have before me any hourly curve of heights in the lake; but it is a general rule of hydraulic work that one obtains greater accuracy by excluding those observations taken during the periods of rapid change in the elevation of the stream which one is gaging. So, while from these curves I do not find the evidence that rapid change of height from hour to hour is a sufficient criterion alone for rejecting the observations, it is a general rule of experimental hydraulics that one gets more accurate, more reliable results by deriving his curves or equations from observations taken at times when the flow is substantially uniform.

Q. It is also a rule of hydraulics, is it not, that in measuring a stream, you want to take its natural, normal condition?

A. Surely, yes.

Q. And if the body of water which you are measuring is one whose surface is fluctuating in different portions of time, you would rather want to measure it in that condition rather than in the stationary condition?

A. No, I should still select periods when the height was not changing rapidly, and expect to get more accurate results.

Q. Although those curves do not indicate that has been done in this case?

A. The observations in most cases fall remarkably well

on the curves. To a certain extent though, this is reasoning in a circle because the equation was derived by averaging these same observations which are plotted here.

Q. Still, though, there is that inherent consistency in the whole work which points to its accuracy?

A. In most cases. I find in some of the other sheets a good many observations where there is a divergence of 5,000 to 7,000 seconds feet from the curve. I find no explanation of that in the curves themselves. I find that for example on September 19, 1899, and September 16, 1899.

Q. How much is that last one off the line?

A. All three observations on that day are about 4,000 seconds feet lower than the continuous curve.

Q. That is about two per cent.?

A. A small fraction over two per cent., nearly two per cent.

Q. Those are errors of observation that are inherent in all observations, are they not?

A. Yes, it is remarkably close; I consider it remarkably close.

Q. As throwing light upon the reduction of any of these observations, I show you a chart on which the discharge measurements of the Niagara River have been plotted in line (handing witness Exhibit ....). Assume that those are accurately plotted, and that it is a copy of the exhibit which is already in the record, doesn't that indicate to you that all the observations fall in pretty narrow range?

A. Within about three per cent. I should say, looking at it now and taking it by the eye rather than by scale.

Q. And you think it would be possible to draw a line through there that would be within one per cent. of the correct line, do you not?

A. Well, within two per cent.

Q. Anyway?

A. Yes.

Q. You would not be surprised if you learned that Mr. Williams had actually drawn a line within one per cent. of the correct line?

A. I should think it were quite possible. I would not be surprised if two independent observers, each trying to work it out as correctly as possible came within one per cent. of each other, in determining an increment from that curve.

Q. And so far as the use made of it in determining the

lowering of Lake Erie is concerned, that would be substantially accurate, would it not?

A. Not necessarily. I said that they might come within one per cent. of each other, but that does not yet say that would be within one per cent. of the truth.

Q. I am assuming that one of them is right.

A. No, assuming the observations are right, they can be averaged by any of the well known methods and get results that are dependable within one per cent. on the discharge. I think one per cent. on the discharge is a little finer than is warranted; but I would think one could get within two per cent., assuming the observations were correct; there was no constant error.

I would like to strike out my preceding answer and say that while the quantity corresponding to any given height can be taken off within two per cent., the increment or variation in discharge corresponding to one foot difference in depth, different observers might vary four or five per cent. within the most ordinary range of heights.

Q. By that you mean that the increment which different observers would deduce would vary four or five per cent.?

A. There is room for very much more variation of increment expressed as percentage than there is for deviation of quantity discharged for any given height.

Q. That is because the difference would be per cent. of a smaller quantity in one case than in the other?

A. That is the idea. Five per cent. I would say was a reasonable divergence on determining the increment.

Q. Do these charts which you have just been examining indicate to you by reason of the consistency of these observations anything as to the accuracy of the observations themselves?

A. No, because there may be some constant error.

Q. Assuming there is no source of constant error.

A. They are a remarkably concordant set of observations.

Q. And the source of constant error which you suggested in your direct testimony, I believe, Mr. Freeman, was under registration of the current meter?

A. Yes.

Q. That was the only material source of constant error as affecting a particular observation, which you laid stress on, as I recall, in the testimony?

A. That was the one I laid stress upon. There might be other sources of error.

Q. But they would be small compared with that, in your opinion?

A. I believe the great source—and I do believe that these observations are erroneous to the extent of possibly 10 per cent—I believe the great source of error is in the disturbed condition of the water in the lower portion of the river, and in the lack of correct registration of the current meter under those disturbed conditions.

Q. It is your understanding that the type of current meter that was used in making these observations under registered in turbulent water?

A. It does sometimes; whether it always does, that I don't know.

Q. Suppose, Mr. Freeman, another section of the Niagara River were measured, where the water was not turbulent, the measurement being made by the same type of meter and under conditions favorable to good work of that kind; and it were found that the measurements as determined from that section of the river checked very closely with those at the International Bridge Section and the open section, which have thus far been considered, what conclusion would you draw from that as to whether or not there was a constant source of error due to the under registration of the current meter?

A. I would not think such a series of observations as you have described conclusive, because being somewhat familiar with the Niagara River, I am by no means certain that there is any place anywhere in that vicinity where one can be certain of the condition of the bottom of the river, or that it is free from more or less boils and eddies. That is I think there are other facts entirely outside of those, which might be mentioned, which prove in the most positive way that there must be some error in these observations.

Q. You say you do not think it is possible to find in the Niagara River any section where the water is comparatively quiet?

A. I would not say that positively without making a more complete personal examination.

I can come right to the point this way by saying that it is much easier for me to believe that there is some error in these current meter observations at Niagara than it is to believe that there is no material yield of water from the drainage area tributary to Lake Erie and Lake St. Clair, during the summer months. And one is forced irresistibly by the facts of record in this case to admit that either the Niagara

gagings are wrong, or that the St. Clair and St. Lawrence gagings are wrong, because subtracting the St. Clair observations from the Niagara observations would show no yield whatever, a part of the time, a part of the year, or no yield of reasonable magnitude from the large drainage area tributary between the Niagara gaging station and the St. Clair gaging station.

Now the fact that when one studies the St. Lawrence observations in their relation to the Niagara observations there is a similar discordance makes it to my mind most easy to accept the solution that the Niagara gagings are those which are in error.

Q. You have read the testimony of Mr. Stearns in this case, a witness for the defendant, have you not?

A. I do not recall. I was present during a part of his testimony I think, but only a part of it, and I have not read the record.

Q. He gave some very specific testimony on the rainfall, run-off, evaporation in the basins of these different lakes?

A. Yes.

Q. Suppose this were the situation: Suppose we took the St. Lawrence discharge measurements, and applying the data furnished by Mr. Stearns as to rainfall, evaporation and run-off, we got a measurement for the Niagara River within less than 5,000 cubic feet of the observed discharge, running over a period of say 16 years, and suppose that when we undertook to go back from the Niagara observations to the St. Clair observations, in the same way, we found a wider divergence, wouldn't the fact that the Niagara and the St. Lawrence checked so nearly indicate to you that what was wrong if anything was that the discharge as stated for the Niagara was nearly correct, while that of the St. Clair had been put down at too large a figure?

A. No, I don't think so.

Q. Why not?

A. I have not all the elements in the problem. I don't know how you work that out; whether you work for the whole year, including the periods when all observations are rendered uncertain by the presence of ice, or whether you are taking only the ice free month. I should want to follow the computation step by step, in order that it would have any weight in my mind.

Q. It is your opinion is it not Mr. Freeman that any study of the physical condition of the lakes as determining the effect

of rainfall and evaporation and run-off is worthless, unless effect is given to the ice condition in the winter?

A. That statement I think is too sweeping. One can discern certain facts, but cannot say broadly that no facts of value can be determined.

Q. That is if you undertook to check the outflow through the river, you would want—

A. If one is attempting to check the mean annual outflow through either of those rivers, one certainly must take account of the ice conditions very carefully; and I believe from my studies of these observations reported in the printed reports of the Chief of Engineers, and such facts as have come before me in this hearing, that one of the greatest sources of error has been the failure to take proper account of ice conditions and of the clogging of the outlets of some of these lakes by ice, during the extremely cold weather.

Q. If you were considering, however, the consistency of the Niagara River with the St. Lawrence, you would take the open season?

A. I would take the open season.

Q. I show you a tabulation which has been prepared, Mr. Freeman, which I ask to have marked Government's Exhibit L, October 13, 1913. (Paper so marked.) In the first column appears the year, June to November; in the second column discharge of the St. Lawrence River per second, as stated in the United States Lake Survey Report 1912, from final study of the observations as to that river. In the next column is the local supply and the storage on Ontario, cubic feet per second. In the next column, number 4, is the deduced Niagara discharge according to the formulae which have been applied by the Government in this case. In the next column the actual Niagara discharge according to the figures which have been presented by the Government in this case.

Now assume that the mathematics of this thing is correct, in addition, subtraction and multiplication, and that we have used the supply and storage as given to us by Mr. Stearns in the testimony for the defendant in this case. And assume that the result of that is that the average actual discharge of the river is about 4600 cubic feet less than the Niagara discharge, as deduced from the formula, and from Mr. Stearns' data.

Now assume if the same method were followed in going back from the Niagara discharge to the St. Clair discharge, and there was a much wider divergence, wouldn't the fact that

the Niagara and the St. Lawrence checked so nearly indicate that it was the St. Clair that was out of line rather than the Niagara being out of line with the other two rivers?

A. Not necessarily, because as I understand this table it is the mean annual flow including the ice period, and I believe—

Q. No, assume that it does not include the ice period; that it is June to November only.

A. I see, now.

Q. (Question read as follows: "Assume that the mathematics of this thing is correct addition, subtraction and multiplication, etc.")

A. If we had no other means of weighing the probable accuracy, that might be true, but I consider that there are inherent difficulties in making an accurate gaging at the Niagara station greater than those at either of the other stations. That is, the conditions immediately upstream from the Niagara gaging station, because of the presence of the bridge, and because of the rapid fall in the river approaching the gaging station, and the disturbed condition of the water, lead one, apart from all other considerations, to have more suspicions about the accuracy of the gagings at that point.

Q. Now suppose Mr. Freeman as a matter of fact that they went down the river to the points which have been marked on the map which I now show you, which is already in evidence in this case, the same being the Survey of the Northern and Northwestern Lakes, War Department, Engineering Corps, suppose, I say they went down the river and measured the Niagara at the section called Section Wickwire and Section Oakfield, that far down (indicating on the map); and the measurements there made checked with those which had been made higher up by one-half of one per cent., would you not say that was a fact to be given considerable weight in determining whether any conclusion was to be reached that the Niagara observations were the ones which were wrong?

A. It should be given weight, but would not alone be conclusive because I notice that at both these stations which you have just mentioned, particularly the section Wickwire, that the river is making a comparatively sharp curve, and that tends to cause disturbances which make it difficult, if not impossible, to measure the flow with great accuracy.

In the first place, that disturbed condition due to the curve causes a tendency to eddying, which may not be apparent at the surface as a distinct eddy, but it gives an instability to the

threads of the current past that section; and it also tends to make the river stand higher on one side than on the other due to the centrifugal force and the deflection of the current by the curve at Section Wickwire, so that this does not appeal to me as a particularly good gaging station.

With regard to the one on the other branch, Section Oakfield, I find also that is not a condition which from the map one would judge to be favorable for accurate measurement. The river also is in a curve at that point, and there are shallows and disturbances a relatively short distance upstream. And then we have no knowledge, so far as I know, as to the condition of the bottom of the river at this point, or how free it may be from boulders.

Q. Wouldn't it strike you as rather peculiar that if the discharge measurements of the Niagara are uniformly about 10 per cent. too small, that in all three of the sections which have been measured, the errors should have been so nearly the same?

A. It is peculiar.

Q. And that this last section should have checked within a half of one per cent. with the sections previously measured?

A. It is remarkable but not convincing, because very likely there is the same boulder strewn condition of the bed of the river at these newer gaging stations as that which probably exists at the previous gaging stations, and in all of those stations there is to my mind, beyond all doubt or question, a seriously disturbed condition of the water at considerable depth below the surface.

Q. Well now to get back to the original question that we had under consideration here: I am assuming that this table in which reference is made to Mr. Stearns' rainfall and evaporation data is correct mathematically; we find when we come to compute it, we start back with the St. Lawrence, go up to the Niagara, and we get within 4600 cubic feet of the observed discharge through the Niagara. Now, assume that you go back from the Niagara to the St. Clair; we find a much wider divergence, having these three sections measured in this way in the Niagara. Does it still appear to you that the mistake is in the Niagara rather than in the St. Clair; or to put it another way, that the entire mistake is in the Niagara and that part of it may not be in the St. Clair?

A. It is probable that part of the mistake is in each of the stations. From studying the descriptions of the several

gagings as given in the reports of the Chief of Engineers, it seemed to me that the conditions for an accurate measurement at the St. Clair were superior decidedly to those at the St. Lawrence, and I cannot get that fact out of my mind and forget it, and assume it to have no weight in the question that you have now asked.

Q. Considering your own statement as to the effect of Lake St. Clair upon the discharge of the St. Clair River, you still think that the conditions for accurate measurement would be more favorable in the St. Clair than in the Niagara?

A. That is my impression.

Q. Now you discussed in your direct testimony, Mr. Freeman, the excavations which had been made in the St. Clair and Detroit Rivers. You spoke of the work at the Lime Kiln Crossing. Just what was the net gain to navigation which was produced by the excavation at the Lime Kiln?

A. I did not put my emphasis on the Lime Kiln Crossing; it was more the excavation at the outlet of Lake Huron, which I considered had affected the situation.

Q. The excavation at the outlet of Lake Huron?

A. Yes. I consider that the excavation at the Lime Kiln Crossing is of minor effect, in comparison with that at the outlet of Lake Huron.

Q. I show you a chart, a part of Exhibit Number 34 in this case, Plate Number 10. (Handing witness same.) You had that before you did you, in reaching your conclusion?

A. Not that particular diagram.

Q. Did you have anything like it?

A. I do not recall it at the present time. I had some other charts. I had several charts, which I have no doubt contain substantially the same information, in another form; but not this particular blue print.

Q. I direct your attention to this portion of your direct testimony:

"It is a matter of plain common sense, as well as of engineering experience that certainly beyond all doubt or question, when a deep channel is thus dredged at the outlet of a lake into a steeply sloping river, that this providing of a deeper and larger gap in the rim of the basin through which the water can flow out will, in the absence of building compensatory jetties or submerged dams along the outlet, have some effect upon lowering the average elevation of the lake, if conditions of rainfall and evaporation and inflow remain the same as before."

A. That is still my opinion.

Q. What did you have in mind there as the "rim"?

A. The portion on Plate 10, which you now show me lying about a mile upstream from the zero of the scale of miles.

Q. What was the extent of the dredging there?

A. As I now recall, without going back over my notes, it had been deepened so that boats of 20 foot draft could now pass where many years ago boats of hardly more than 10 or 12 feet could pass, possibly even less draft in the earlier days.

Q. What was the width of the waterway there which was opened up, as you understand it?

A. I can't say what width. I had before me at that time one of the latest charts of the outlet of Lake Huron, and also the earliest chart that I could find, but I do not now find a copy of that early chart.

My recollection is that originally there was a broad bar at the outlet nearly opposite the Ft. Gratiot Lighthouse, and I am quite certain that I found notes of a channel having been dredged through that bar, and that the latest charts show ample water there for a boat drawing upwards of 20 feet to go through.

Q. Have you your notes with you Mr. Freeman on that subject?

A. Only a part of them. I find a copy of one map but not of the earlier one.

Q. I wish you would look through them between now and to-morrow morning, so that you can state in the morning when we come back just what you had in mind there, when you spoke of opening up the rim. I want to know just what you had in mind.

A. I can state that very clearly now. I had in mind not only the work that had been done by the Government in dredging, but also the work that has been going on by natural process of scour by the ice jams there. That I am informed is a hard pan bottom and that that has been scouring, by the force of the current, within the historic period; and I included in the effect the natural scour, and the dredging for the improvement of navigation.

Q. Now we have here the map of Lake Huron. Just where do you understand that that particular work was done, referring to Lake Survey Map of the St. Clair River?

A. Isn't there an earlier chart? I do not find a copy of it. I recall having another chart from the one now

shown me, a much earlier one, which indicated a bar about opposite the Ft. Gratiot Lighthouse. (Counsel hands witness a second chart.) It is Plate 7 of Williams' Exhibit 34.

Now, from comparing Plate 7, Williams' Exhibit 34 with Plate 8,—and I recall particularly that I also referred to one of the latest charts, I was convinced that there had been a very material deepening at the outlet, precisely at the outlet of Lake Huron.

Q. It is the dredging you are referring to?

A. Dredging and natural scour. I have no doubt that in every winter when there is an ice jam, that there is a noteworthy scour takes place, tending to increase the waterway, and also to a lowering of the level of Lake Huron.

Q. I show you your Exhibit, J. R. F. Exhibit Number 1, on which appears a bar dredged at the head of the St. Clair River?

A. Yes.

Q. In 1895. Is what you had in mind there the same thing that is marked on Plate 10, Williams' Exhibit 34?

A. I presume so.

Q. As excavated material? Just where do you understand that to be?

A. Well, from the scale, that appears to be further up into the lake.

Q. That would be away up here wouldn't it? (Indicating.)

A. Yes.

Q. At that point, the lake would be three or four miles across?

A. That particular dredging, a mile or more up the lake, would have no particular effect on what I was considering. But the natural scour at the outlet of the lake would; and also the difference shown by the Chart Plate 7, Williams' Exhibit 34, as compared with the more recent charts.

Q. Then on this J. R. F. Exhibit Number 1, these broad lines are drawn very high in the years 1895, 1896 and 1897, in the second line down Lake Huron?

A. Yes.

Q. They would not have any very appreciable effect—

A. No, not at that distance, they would not have any appreciable effect.

Q. I call your attention to this Plate 10 of Williams' Exhibit Number 34 and ask you to look at the map and see where the excavation that is marked here "Lake St. Clair, excavated material, U. S. Ship Canal," two places at both ends of Lake

St. Clair, where that was and see whether that had any appreciable effect or not. There are three channels of the river as they come out there, are there not?

A. Yes.

Q. And through this particular channel, there is 30 per cent. of the water flows, does it not, from your understanding of it?

A. That would not appear to be unreasonable, judging by the soundings and the length and width, as shown on the chart.

Q. Having in mind the place where that excavation was made, in your opinion would that have any appreciable effect, when you take into consideration the width of that lake?

A. Some slight effect, but not much.

Q. Let us take the one at the lower end of the lake. Would that have any very great effect?

A. No important effect, no, because of the great width.

Q. Now let us take this plate number 10, Exhibit Number 34, with the portion marked "Excavated Material" at the mouth of the Detroit River. Bar Point Light is the one, and the other is Ballard's Reef.

A. The excavation down stream from Bar Point, I should not expect to have any material effect; that is the excavation opposite Bar Point.

Q. Now do you find anything in this dredging shown on this Plate 10 of Exhibit 34 that appears to have had any appreciable effect upon the discharge of these rivers?

A. I would not expect the excavations shown there to have any important effect.

Q. How about your Exhibit J. R. F. Exhibit 1, then?

A. I was under a misapprehension. I supposed that that particular excavation (indicating) was nearer the head of the river.

Q. You mean the one "Bar dredged at head of St. Clair River"?

A. Yes.

Q. If as a matter of fact it was out in the lake some distance, that would not have any very appreciable effect?

A. No.

Q. And there is nothing else either that would have any great effect?

A. No, we have then left the natural scour.

Q. Had your attention been called to the fact, in the preaaration of these tables, that of the material which had been

taken from the St. Clair River, all of the material, with the exception of 7,167 cubic yards, was deposited in the St. Clair River in the vicinity of the work, and that 7,167 cubic yards was dumped in Lake St. Clair?

A. I think that fact was within my knowledge, yes.

Q. And did you also know that the material which had been removed from Pine River, and from Bell River, was deposited in the St. Clair River?

A. I am not so clear about that, but if it had been, it naturally would be deposited in some deep portion, where it would not materially retard the flow.

Adjourned to Tuesday, October 14, 10:30 A. M.

October 14, 1913, 10:30 A. M.

Met pursuant to adjournment.

Mr. Austrian: With regard to Government's Exhibit M, that you (Mr. Wilkerson) identified yesterday, on the cross-examination of Mr. Freeman, I want to save the record.

This Exhibit M, as I understand it from the Government's counsel, was marked for identification and used upon the cross-examination of Mr. Freeman. Yesterday afternoon, upon the examination of Mr. Freeman, was the first time that this table had been submitted to any witness for the Defendant or any counsel representing the Defendant. During the recess from yesterday until today, we have examined this table and we find it to be, in our opinion, inaccurate, not based upon facts; the conclusions therein expressed not warranted by facts. And so as to preserve the record, we move that the cross-examination of Mr. Freeman, in so far as it is based upon said table, or anything pertaining to said table, be stricken out.

We take it, of course, the Government intends to prove the correctness of that table; but we do not want to be in the position of having waived this objection, upon the conclusion of the cross-examination of this witness.

Mr. Wilkerson: Of course the table is offered merely for identification; and the witness was interrogated upon the subjects therein referred to, upon the theory that the computations were accurately made. The motion may stand and be disposed of, after the table has been introduced in evidence in the ordinary way. Of course if the table is not introduced in

evidence, the cross-examination of the witness on the table will go out. If it does go in evidence, counsel for the Defendant will have their opportunity to show the particulars in which the table is inaccurate.

Mr. Austrian: I concede the questions were put to the witness on the theory that the table was accurately computed, but I believe some questions might not have contained that hypothesis.

Mr. Wilkerson: I intended in any question which I put to the witness—and I assumed that that element was carried forward in the questions—I assumed the accuracy of the computation of the tables. It might be, if there is anything in the record that should be modified, if pointed out in what particulars it is claimed the table is inaccurate, that might save time.

Mr. Austrian: We have absolutely no objection to pointing it out, so far as we have been able to ascertain it upon a very hasty examination. You want those in the record, those suggestions?

Mr. Wilkerson: Yes. If there is any portion of the testimony of the witness, which would be modified in any way—

Mr. Austrian: Mr. Freeman has not examined the table, but Mr. Williams and Mr. Stearns have.

Mr. Adcock: I think Mr. Freeman has examined it.

Mr. Austrian: No, he has not examined it. I understand from Mr. Williams and Mr. Stearns that there are inaccuracies in this table. I would like to have Mr. Williams point them out to counsel, because he has them in mind, and I have not.

Mr. Wilkerson: You want this in the record?

Mr. Austrian: Just as you like.

Mr. Wilkerson: Let it go in.

Mr. Austrian: No objection.

Mr. Wilkerson: The table really explains itself. We can have somebody swear, who made the computation.

Mr. Adcock: Here is the proposition: Ordinarily it would not be necessary to prove these tables, because we could check them up, without any trouble—

Mr. Wilkerson: I am perfectly willing to have him call attention to the points in which you claim either the theory upon which the table is made is incorrect, or the mathematical work is inaccurate.

Mr. Austrian: Point it out Mr. Williams, please, just the inaccuracies.

Mr. Williams: We find on checking this table, from the year 1891 to 1898 inclusive, the discharge through the Welland and Erie Canals has been introduced into the table twice, thereby increasing the discharge of the Niagara River, and reducing the difference between the derived Niagara and the actual Niagara.

We find furthermore that the discharge of the St. Lawrence purports to be derived from an equation contained in the 1912 report. We find upon examination that the equation there only represents the years from 1904 to 1906, and that there is no equation there which represents the discharges of 1891 to 1903, unless there is something there that we have not been able to find.

Mr. Wilkerson: Mr. Shenehon, will you explain how the table was made.

Mr. Austrian: Have you any other explanation Mr. Williams?

Mr. Williams: No, that is enough.

Mr. Shenehon: Column 2, St. Lawrence River outflow, by U. S. Lake Survey 1912 Report, does not refer to the annual report of the Chief of Engineers, but to a report by Sherman Moore. I have a blue print of the curves of the chart of the Niagara River for the period prior to 1904, and for the period after 1904.

Mr. Williams: You said "Niagara"; you mean St. Lawrence.

Mr. Shenehon: I mean St. Lawrence. That was submitted by me to Defendant's witness, Mr. Frederic P. Stearns, last night. Both the curves for the condition prior to the building of the Gut Dam and the condition after the building of the Gut Dam are shown on this sheet, and were used in preparing this table. The error of Mr. Williams was in assuming the report was the annual report of the Chief of Engineers.

The equation given in that has to do with the condition after the building of the Gut Dam only. As to the inclusion of the 2300 cubic seconds feet twice in the period from 1891 to 1898 inclusive, that is a matter I will need to check up to see whether or not such an error did come in.

Mr. Wilkerson: How much difference would that make in the result, assuming it had been done?

A. Not to exceed 1,000 cubic feet per second, roundly.

Mr. Adcock: What do you say about that Mr. Williams?

Mr. Williams: Something over 1,000 cubic feet, between 1,000 and 1,500 on the average.

Mr. Wilkerson: It will not be more than 1,500.
Mr. Shenehon: It is really half of 2,300.
Mr. Williams: Pretty nearly.
Mr. Shenehon: It is half of the period, provided that error was made.

JOHN R. FREEMAN, resumed the stand and testified further as follows:

Cross-Examination Resumed.

Mr. Wilkerson: Q. Mr. Freeman, I asked you some questions on yesterday with reference to a number of observations on the Niagara River which had been rejected by Mr. Williams in his study of this case. Did you observe when you went over his figures that out of 219 observations at the International Bridge, and 121 at the Open Section, making a total of 340 observations in the original computation, only 129 in all were used, and ten of those were afterwards eliminated, for the reason they were winter observations, making a total of 119 observations which were used. That is to say that of a total number of available observations on the Niagara River, 65 per cent. were rejected. Did you have that fact in mind?

A. I recall that a large number were rejected, but I do not remember the precise proportion.

Q. Now let me direct your attention to Sheet 1 of Table XLV A, of Williams' Exhibit 34.

A. I have it before me.

Q. Now I direct your attention to Group 3 of that Table. Having in mind what you have said with reference to taking the lake at a quiescent time, what range of lake level do you find there between the 15th of the month, October, and the 17th, in column 4?

A. .89 of a foot in elevation.

Q. 572.03 is it not and 570.64?

A. Strike out my answer. I had not followed down to the lowest on the 17th. I find a range from the one observation given on the 15th, at which time the elevation of the lake was 572.03, and the latest observation on the 17th, at which time the elevation was 570.64.

Q. There were two observations on the 15th, were there not?

A. The second observation on the 15th I should say to the fourth observation on the 17th, at which time the elevation was 570.64, a range of 1.39 feet.

Q. Now I direct your attention to Column 6. You find included there in determining the mean of the daily rate elevation at Buffalo, to which discharge observations were referred, reading at the top, 572.15, do you not?

A. I do.

Q. And you observe that the average daily mean elevation of the lake at Buffalo to which these discharge measurements was referred is 571.89?

A. I do.

Q. And you observe that the average of the observed elevations, at the time of the particular observation was 571.36?

A. I do.

Q. That there is a difference between the actual average of the elevations, and the mean to which the observations are referred of .53 of a foot?

A. I do.

Q. That is to say the effect there is to refer the discharge measurement, after it is weighted, 184,471, to a lake elevation which is .53 of a foot higher than the average of the actual lake elevations at the time of the observation?

A. That appears to be the fact.

Q. That would make a difference of about 11,000 cubic feet per second in the figure of discharge, wouldn't it, assuming an increment of 22,000 cubic feet per second?

A. Approximately, yes.

Q. Now what do you think Mr. Freeman of including, in determining the increment for this river, a group of observations in which there is that difference between the lake elevations to which the observations were referred and the average of the actual observations, and in which there is a range of 1.39 feet in the way in which it appears in that group?

A. I have no doubt that some correction should be made to allow for the progress of change of stage from the foot of the lake down to the gaging station, because not only must one allow for the wave to pass down, but there must also be time for a more or less filling or depletion of the basin in the vicinity of the gaging station.

Now just how much that correction should be, I had no means of determining last spring, but since you showed me a curve on which the hourly observations were plotted yesterday, one could from that make a somewhat closer approximation

for the purpose of learning just what correction should be applied.

Q. I wish you would direct your attention now to these curves that were shown to you yesterday, and give us your view on that subject at the present time?

A. (Witness refers to same.)

Q. In the chart to which you are referring now there are three curves, one of which indicates the Lake Erie elevation, another the volume of discharge, and another the Niagara River elevation at the Gorge Pool of the Niagara River, at Suspension Bridge. These sheets are marked Exhibits F, G, H and I.

A. I do not find one of these sheets, the one that covers the period referred to on October 12.

Mr. Wilkerson: I do not think that is plotted.

Mr. Shenehon: We did not have a self registering gage at that time, so that is not included in this series.

Mr. Wilkerson: Q. From those curves there, it appears it takes the effect of the river about how long to travel down to the Gorge Pool?

A. The time of travel from the lake down to the Gorge is variable, but appears to be in general about four hours I should say, from a hasty examination.

Q. Between three and four hours probably?

A. Something like that, yes.

Q. If it takes it that long to travel down to the Gorge Pool, how long will it take it to travel down to the—what I am trying to get at is how much of an allowance ought to be made in correcting these observations, so as to make allowance for that time to travel the distance?

A. Looking at the map now, in the light of these curves, for the first time, I should say somewhere about an hour or two.

Q. Not more than two hours?

A. No.

Q. By that you mean the time it takes the river to fill up as far as Chippewa?

A. Well, the time for the effect of a change in lake level to fully affect the regimen of the stream at the gaging station.

Q. Well, the effect of that, while the river is going up is one way, and while it is going down it is another way. In a certain sense that is compensating?

A. I could not say as to that without more time to investigate it. One must consider the filling or depletion of the basin

all the way between the outlet of Lake Erie and the brink of the falls, or of the rapids at Chippewa, which is a distance of something like 20 miles more or less; and from the fact that apparently the peak of a wave takes approximately four hours to travel from Lake Erie to the Pool below the Falls, I should say approximately that it would take somewhere about two hours for that effect to become established at the gaging station; that is for the pool to come to a corresponding stage with the elevation at the outlet of the lake.

I think the wave itself, the peak of a wave, would be transmitted more rapidly than that.

Q. What I am trying to get from you is an expression of your views as an Engineer as to the propriety of including in these computations in that column 6 that mean daily elevation for the entire day prior to the period covered by the observations?

A. Well, at that time, in the absence of hourly gages like that, that seemed a reasonable first approximation. Now we have data for a closer approximation.

Q. Would you say that in this group 3, to which I have directed your attention, the stage which had been selected was a quiescent stage of the lake?

A. This period is not covered in the four sheets of diagrams which you have shown me, but Mr. Williams shows me another plotting on a smaller scale, which I presume is an exhibit in the case, Chart 4 Sheet number 1, Williams' Exhibit 35, giving the elevations of Lake Erie at Buffalo for September and October 1898; and that diagram indicates that Lake Erie was then in about as stable condition as it is ever found.

Q. I was referring to those observed elevations which indicate a change of 1.39 of a foot in a period of two days. That shows on this Chart 4 Sheet 1, on the 17th day of October, in the form of a sharp depression, does it not?

A. It does, yes.

Q. It is the sharpest depression that you find within a month, is it not, prior to that time?

A. It is sharper than any during the preceding month.

Q. Now I direct your attention to Table number 45 of Williams' Exhibit number 34.

A. I have it before me.

Q. Which is a summary of the computations relating to the Niagara River, and I will ask you whether or not you do

not find that the range of elevation which is considered in this computation is 1.21 of a foot; 572.62 and 571.41?

A. I do.

Q. In the computations which were made by the Government Engineers, there was a range of lake elevation taken into consideration of 3.9 feet, approximately?

A. Something like that, as I remember it from the diagram you showed me yesterday.

Q. Now is it not a fact that where you have a small range of elevation, there is difficulty in getting an accurate measurement of the increment?

A. That is true. It is better to have the greater range.

Q. I also want to direct your attention to another one of these tables in Williams' Exhibit 34. I refer to table number 25 of Williams' Exhibit 34, in which a series of increments for the St. Clair River are derived by comparing the discharge measurements where there is a very small range in elevation.

Take the first column there, the number of observations in the period 3. And then we come to column 5, the one which is the center of gravity at 580.35; and column 7, where we have the center of gravity at 580.32, a difference of .03 of a foot, from which an attempt is made to deduce the increment from the difference in the discharge measurements.

Now, isn't the effect, the evident effect of comparing elevations where you have a very small range that the fact you have such a small divisor, that is such a small decimal for a divisor, multiplies and exaggerates any error of observation which there may be in the observations as to discharge measurements?

A. It has that tendency.

Q. So where you come to compare elevations of very small range, you could group observations in such a way that by reason of the small divisor which you would have, errors of observations would be greatly magnified. Take the third line there, for instance, where you have a range of only .04 of a foot; an attempt is made to deduce an increment from such a small range as that, 580.37 and 580.33.

A. Those two observations give a small base for deriving an increment, if taken alone.

Q. There are others that have a larger base. But now, take the fifth line where you have a difference of .13 of a foot, and in the sixth line you have .11. The point that I am trying to get at and make clear is where you do have

a small range of observations the effect of that is to magnify errors of observation?

A. That is true. It is not a good condition for determining an increment.

Q. So that in that respect, so far as the elimination of errors of observation are concerned, the method which would give you a wider range would be the more desirable, would it not?

A. Yes, but in that same table there are cases which give a much wider range.

Q. Yes, but in getting at the total result, they have been combined with figures where an error of observation may have been magnified by a very small divisor. That is true, isn't it?

A. Yes.

Q. Dean Shenehon directs my attention here to Sheet number 2 of this one curve series, Exhibit K, October 8, 1913. On this point of accurate observations when the lake is in a fluctuating condition, I direct your attention to a period, November 3rd, 4th and 5th, 1899. You observe there do you not a very wide fluctuation?

A. I do, yes.

Q. In the lake, and yet the observations, the actual observations appear to be plotted almost exactly on the line.

A. Well, the curve was in part determined from those same observations.

Q. That is true.

A. They do follow the line.

Q. But they are consistent with each other at least.

A. They are, yes, remarkably so.

Q. Well, that would be the proper way would it not of deriving a curve; you would take all the observations, and then the curve being derived from all the observations, if there was any one particular observation that fell into its proper place when plotted, that would indicate that the curve was a substantially accurate one, would it not, to an engineer?

A. Yes.

Q. You understand the method of weighting these observations, which was used by Mr. Williams in this case, do you, Mr. Freeman?

A. I have forgotten just now. I went over with him his

method of weighting, at the time, six months ago, when I was studying his observations, or computations.

Q. The effect of it, as you understand it, is that if you have a single observation made on one day, and four or five observations made on another day, that the single observation has given to it the same weight as the average of all the observations on the day on which there were four or five?

A. I don't recall. I think they were given different weights. I could tell by referring back.

Q. Well, they were weighted by time intervals. Just why shouldn't all observations be given equal weight in reaching a result of this kind? In other words why isn't one observation just as good as another, without regard to the time when it was made? For instance take this November 3, 4 and 5, 1899, which we have here. Now we have two observations which were made on the 4th of November, and we have two observations which were made on the 3rd of November and two on the 2nd and we have one on the 1st.

Mr. Williams: The 30th and 31st were also included in that, for the preceding month.

Mr. Wilkerson: Q. Take the 30th and the 31st. I find on the 1st of November there we have one observation. The effect of this method, as I understand it, is to give to that particular observation a greater weight than any other one observation which is made, is it not?

A. As I recall, yes; as I recall Mr. Williams' computations.

Q. What I am trying to get at is why one observation is not worth just as much as another, the same as an astronomical observation?

A. Well, in one case there were two observations taken on the same day, one as soon as possible after the other. And in that case (indicating) there was only one taken for a period of several days, and whether the two observations were grouped together for giving the result of a day's determination, and the whole were averaged by days rather than by individual observations would depend somewhat on other conditions, as to wind, or disturbed conditions.

I see now from looking at this curve of hourly heights no reason why one is not as good as another, except that on November 4, the first observation of that day appears to be at a time immediately following an extremely rapid rise of the lake; and it is a general rule of engineering investigation to exclude observations taken when the conditions are vio-

lently and rapidly changing, with the idea that the regimen of flow at the gaging station may not have been brought into entire harmony with the height at the outlet of the lake, which produced that condition.

Q. Can you see any reason as an engineer why in treating these observations you should,—rejecting, if you please, observations taken under abnormal circumstances—but so far as observations which were taken under what you conceive to be normal circumstances, can you see any reason why one observation should not have just as much weight as another, without regard to whether it was taken on one day, or whether two happened to be taken on another day?

A. I see no good reason at the present time.

Q. There is another rule—I suppose we call it a rule—that those who have to do with generalizing from observations follow, engineers, astronomers, and that rule is this is it not Mr. Freeman, that the selection of observations or the rejecting of particular observations is a thing which is to be indulged in with the very greatest care?

A. That is true.

Q. For the reason that if you once commence to select, or commence to reject, the computer may make his selection or rejection having in mind an ultimate result, and that it is a thing which should not be done unless it is perfectly clear that there is some extraordinary circumstances which makes the rejection absolutely necessary?

A. That is a general rule of reducing observations.

Mr. Wilkerson: Here is a chart that we have not had identified before. This is Complainant's Exhibit N, for identification.

(Whereupon chart produced by Government's counsel was marked Complainant's Exhibit N, for Identification.)

Q. This chart purports to show—and for the purpose of all the questions which I shall put to you based upon it, I shall ask you to assume that it correctly represents the level of Lake Ontario with respect to Lake Erie before and after the change in regimen of the St. Lawrence river due to the construction of the Gut Dam, and indicates correctly that in the period following the construction of the dam, Ontario appears to be fluctuating in about 6¾ inches higher elevation as compared with Erie in the earlier period. Now what I wish to ask you is this: Whether or not in case there was a change in the regimen of the river such as that caused by the construction of the Gut Dam, and you were to plot

the observations for the two periods, you would expect to find the change in the regimen indicated by a change in the line such as is shown on this chart?

A. Other things being equal, I would expect to find some such difference; but I think that would be an extremely doubtful and uncertain method for measuring the effect of a change like that of building the Gut Dam, because many other circumstances which would affect the level to a greater magnitude may have come in to obscure that result. That is the ice conditions may have been different in different years, or the rainfall conditions in the two regions might conceivably have been somewhat different. The cause to which I should attach the most importance as a possible disturbing element would be a variation in the ice condition as affecting the outflow of either one or the other of the two lakes, and I think that might entirely obscure any such effect as that of building the Gut Dam.

Q. But if you had two periods long enough so that there was an opportunity for this difference due to ice conditions to compensate each other, you would expect running over that period to find the force which was continuously operating to be indicated by a change in the line as drawn on the chart, would you not?

A. Yes; the effect must be there, but it may be obscured by other disturbing causes.

Q. Of course if you only had two or three years, that would be one thing, but if you had 44 years in one case and 9 years in the other, there is a very fair opportunity for those other disturbing forces to compensate each other, is there not?

A. No, I do not think there is because there are many things that may have occurred. That is it occurs to me at the present moment that there has been a changing condition in keeping the river open at Ogdensburg, between Ogdensburg and Prescott for a ferry; that is in the running of an ice ferry there which might affect the winter height. It is entirely conceivable that the development of water power in the past ten years at Niagara; their building of ice booms and taking various precautions to reduce their ice troubles may have in some way affected conditions. And I think that a nine year period since the building of the Gut Dam is entirely too short to average up the seasonal effects of much greater ice obstruction in one river than the other.

Q. The other factors remaining the same, that one continuous factor would be apparent as drawn?

A. Yes.

Q. You were speaking yesterday of this change of regimen in the St. Clair river. I show you another chart, which has been offered here for identification, on which the relative fluctuations of water surfaces of Lakes Huron and St. Clair, means of six months period, June to November inclusive, have been plotted; the equation used being the United States Lake Survey equation from all data in the Report of 1912, page 3546. Do you see in that chart any indication of a radical change in regimen of the St. Clair river during the years 1889 and 1890. I call you attention to the fact that was the open season, so that there could be no question about ice. For the record, those since 1889 and '90 are in red; those prior to the period are in white. (Handing witness Defendant's Exhibit B for identification October 13, 1913.)

A. The number of observations is too few to make them conclusive; and they also disagree very widely among themselves, but so far as one can deduce anything from them, they indicate that there has been a change and that for the same elevation of Lake St. Clair at the Flats, Lake Huron formerly stood something like .3 of a foot higher than at the present time.

Q. You do not see anything there that indicates a change of from six inches to a foot, do you?

A. The observations are too few and too inconsistent to be conclusive as to how much the change has been. But so far as any deduction can be drawn from that, it should be drawn by two curves, one for each of the two periods shown; two lines on there, one line for each of the two periods shown. And those lines would not coincide, but one would come decidedly above the other, enough to show that there has been some change.

Q. What in your opinion is the cause of that difference between the two periods, about which you have just testified?

A. I think the most reasonable explanation that I could offer for that is the dredging that has been going on, and also the natural scour at the outlet of Lake Huron.

Q. How about difference in ice conditions?

A. The scour caused by ice conditions; and then the storage because of ice conditions, the holding back of the water by an ice jam may affect this. I think the observations are too few of themselves to establish the fact of the amount

of change, clearly. They do indicate that there has been a change, and they are not of themselves competent to show what has been the cause of that change.

Q. You testified to some extent on the subject of run-off from these different drainage basins, as I remember your testimony, Mr. Freeman?

A. I did study into that, yes.

Q. Did you study the run-off conditions in the basin of Lake Erie as compared with that of Lake Ontario?

A. Why in a general way, yes; but not in very great detail.

Q. You examined the computations which Mr. Williams made on that subject, all the tables that he prepared?

A. Yes, and I also examined some that Mr. Stearns had made; and I also examined some computations given in an Appendix to the Report of the Chief of Engineers, by one of the Assistant Engineers.

Q. I wish you would look at the table 59 A in Exhibit 34 of Williams' discussion of this case. Did you give consideration to that table?

A. I cannot now recall particularly. I saw a number of computations of Mr. Williams, but it was six months ago; and I do not at the present moment recall this particular table.

Q. It is a fact is it not that the run-off conditions in the basins of Lake Erie and Ontario are very materially different, as you understand it, Mr. Freeman?

A. I should want to look that up. I should want to go back to the observations before answering specifically.

Q. Well, you know in a general way, do you not Mr. Freeman, that around Lake Erie it is very level country, is it not?

A. Yes.

Q. And cultivated?

A. Largely so, yes.

Q. The whole situation is one where you would expect to find, comparatively speaking, a very small run-off, would you not?

A. I would say small rather than large, but I am not prepared to say just how much smaller than average conditions.

Q. Did you read Mr. Williams' testimony on this subject?

A. I do not think I did.

Q. The streams were measured, gaged, and from that the conclusion was reached as to the run-off of these dif-

ferent drainage basins; and the point to which I am directing your attention is the small run-off of Lake Erie as compared to the other two lakes. Of course we all understand that observations of this kind, so far as accurate results are determined, they are exteremely indefinite, but so far as comparisons are concerned, we might be able to get some help from a study of this kind?

A. Well, I may say that in general from a flat, a highly cultivated territory, one expects a somewhat smaller percentage of run-off than from a steep and forested territory. I think to a large extent around both of the lakes, certainly as regard the extreme eastern end of Ontario, that also is a cultivated country.

Speaking in a general way, I may go further and say that from a flat, cultivated area we do sometimes have exceedingly heavy run-offs, as for example the great floods in Ohio during the past year; and that the total annual run-off comes largely in a season of the year when the ground is frozen and not receptive of the water, so that the cultivation does not have as much influence then as on the summer flow. I would not want to be specific without taking a good deal of time to study all the available data.

Q. I was speaking particularly of Mr. Williams' conclusions there as shown in Table 59 A for the months June to November, the last line.

A. I have not examined that sufficiently to have any opinion of my own upon it.

Q. In determining the effect of the run-off from the drainage basin upon a lake, if you were trying to get at the effect for the period of navigation, say from June to November, would you take into consideration the figures for the full year, or for just that portion of the year during which you were trying to get at the effect?

A. I should want to consider both, because the winter rainfall largely sinks into the ground and comes out and feeds the streams as ground water during the summer; but in considering the effect of lake levels during the open season, I should of course give the principal attention to the summer run-off, or the run-off between April and November, or rather from June to November after the ice is out of the lakes.

Q. Have you any reason to question, as an engineer, the conclusions which Mr. Williams has reached that comparing Lake Erie and Ontario, whether you take the full year or

any part of the year, the run-off for the Erie basin is considerably less than ½ that of the Ontario basin?

A. It looks reasonable to me because Ontario at its western end receives the Oswego river from the Adirondacks, from a forested area; and Huron and Michigan receive a good deal of water from forested areas, so from those facts I should think it reasonable to expect that the run-off of the area, the drainage basin, which has a larger proportion of cultivated land would be relatively smaller.

Q. Now, I understand Mr. Freeman that in its last analysis, your criticism of this Niagara discharge measurements reduces itself to the belief that they must be in error for the reason that if they were accepted as accurate, there was no showing of a sufficient contribution from Lake Erie?

A. That was the principal reason.

Q. When you reached that conclusion, did you have clearly in your mind this very great difference between the run-off in the Erie basin and the Ontario basin?

A. I did have in mind that there was probably some difference, but I am not yet ready to admit that it could be so great as to explain that discrepancy between the Niagara gagings and the gagings at the head of the St. Lawrence and at the outlet of Lake Huron.

Q. It might be big enough to account for part of it, if there was a wide difference?

A. It might account for part of it, but it is inconceivable to me that it could account for the whole of it.

Q. What was your understanding of the extent of the difference between what Niagara ought to show as the discharge observations and what it did actually show?

A. In round numbers 20,000 second feet.

Q. I do not know whether you heard Mr. Stearns testify or not. I think he puts the figure at 16,000.

A. I did not hear him testify. My own recollection is more than 20,000 rather than less, as I viewed it and figured it out.

Q. But without having your attention directed to the great difference in the run-off of the two basins?

A. There are other differences too, in the relative areas of water surface of Erie as compared to its drainage area, its land surface, and that of the other lakes. I tried to consider and properly weigh various elements, not only the fact that the Erie drainage area was flat, but I also tried to

give proper weight to the relation of the land area to the water area.

Q. You reached the conclusion, as I understand, that on the lake surface the evaporation is greater than the precipitation?

A. Probably a little, yes.

Q. That would be true of Lake Erie?

A. Even that is somewhat uncertain because we have no very good observations on the actual evaporation from very broad surfaces such as Lake Erie. All the data that we have indicates that it is proportionally less on a very broad area than it is on the area of an ordinary water works reservoir, or particularly on the area of an experimental evaporating basin.

Q. I thought your conclusion was that the evaporation was probably greater than the rainfall on the surface of the lake; it may be Mr. Stearns' conclusion not yours?

A. Yes.

Q. I thought you both reached that conclusion?

A. I think it was somewhere nearly that, probably a little greater, but my own ideas as to the evaporation from broad lake surfaces are that it is only about say two-thirds as great as one would derive from experiments on a small evaporating basin.

Q. And the basin of Lake Erie compared with the surface of the lake is smaller than Lake Ontario, is it not; the drainage area as compared with the water surface of Erie is smaller than that of Ontario?

A. The ratio in the case of Lake Erie is that the water surface compared with the total drainage area is as one to 3.47, while in the case of Ontario it is as 1 to 4.55; and in the case of Superior it is as 1 to 2.37; and in the case of Michigan 1 to 2.95; and in the case of Huron 1 to .313. So that taking the lakes as a whole, all of the Great Lakes have a ratio of water to total drainage area of 1 to 3.02, while Erie has a ratio of 1 to 3.47; that is the ratio of water to the entire drainage is less for Erie than it is for the Great Lakes system as a whole.

Q. I was speaking however of this difference between Erie and Ontario, and of the apparent discrepancy between these discharge observations for the St. Lawrence and the Niagara. What I wanted to ask you was this: Whether in your opinion in comparing the Niagara with the St. Lawrence you had given enough weight to the fact that the drainage area of Ontario is as one to 4.55, while that of Erie is 1 to 3.47; and that

the run-off as shown by the tables of Mr. Williams of the Erie Drainage Basin is considerably less than ½ of that of Ontario, when you look at it for the entire year, or for the season from June to November; and if you look at it from June to November it is really about ⅓, less than ⅓ for Ontario?

A. I believe that I did give proper weight to that.

Q. So far as you are familiar with the physical conditions of the country, they all tend to show that that conclusion which Mr. Williams has stated in his table about the wide difference in run-off is in accordance with what you would expect from the physical conditions

A. I should expect the difference to be in that direction.

Q. I am not speaking of the accuracy of the particular figures themselves, but I am speaking of the relative condition as shown by the tables.

A. Yes, as I have already stated.

Q. You spoke also about the difficulty of measurement of the Niagara river. We are not to understand from any criticism you have made about the Niagara river, we are not to understand you have ever actually done any work on the Niagara river in the neighborhood of these gaging stations?

A. I have done no water gaging work. I have done more or less engineering work on the Niagara river.

Q. Have you made any soundings?

A. No.

Q. So that what you have said about the condition of the bottom, and these other things, is your understanding based upon what you have heard and read?

A. What I have heard and read, and photographs that I have seen. And then I have had occasion to go along the river very frequently, and cross it at one point and another many times.

Q. You were never down at the river at these new sections that have been measured?

A. No, I have never been there when they were gaging.

Q. You have observed the International Bridge Section, have you?

A. In a general way, yes.

Q. Well that brings us back to the subject we were discussing here yesterday; that is if the error in these discharge measurements in the Niagara is due to the fact that the water is in a disturbed condition, you would expect to find a variation which would be in proportion to the extent of the perturbation, so that if you found that these three sections checked,

it would indicate that the river could be measured pretty accurately. I just want your view on that.

A. The tendency of these later gagings is plainly to confirm the other gagings, but still both combined tell a story that to me is wholly inconsistent with the story told by the gagings at the St. Lawrence and the gagings at the St. Clair and the obvious facts about the run-off from Lake Erie. It is like the case where one has discordant witnesses testifying as to a fact, and you have the question as to which witness you shall believe when it is physically impossible that all of the witnesses can be telling the truth.

It is much easier for me to believe that the disturbed condition has caused constant errors in the measurements at both of the Niagara stations than it is for me to believe that the drainage area of Lake Erie contributes nothing whatever to the flow of the Niagara river during the open months. And then in studying the Niagara gagings, those that I had the opportunity to study in the record at the section at International Bridge, and the other immediately below it, with a view to seeing whether I should believe the gagings at the St. Lawrence combined with the gagings at the St. Clair, in preference to the Niagara gagings, it seemed to me in that case we had two independent witnesses, both of whom were perhaps better qualified than this very much disturbed witness at the Niagara.

Q. That is when you had only the two sections?

A. I made those considerations, of course, from the two sections. Now that this third section has been introduced, I see possibilities for error in the statements of that witness; that is because of the curved condition of the river at that point. It is a very puzzling state of affairs. And the different sets of gagings are discordant when compared with one another, although all of them remarkably concordant among themselves.

Now if we had nothing to go by but these gagings at the Niagara, and were studying their consistency among themselves, I would be lost in admiration of their remarkable agreement with one another. But I have had cases like that in my own practice. I think I referred to one where I made some water gagings in testing a turbine under disturbed conditions, and I saw no reason at first to think that these current meter gagings were in error, but I found they were inconsistent with other gagings; and then sought for the error and finally found it.

Q. Well, what would you say Mr. Freeman suppose it appeared that so far as the run-off of the Erie basin was concerned, we would accept what Mr. Williams stated here as the correct result for that, and applying the method which has been used by you and Mr. Stearns here, and by making the allowance for the smaller run-off of Lake Erie as shown in Mr. Williams' tables, we would find that the St. Clair and the Niagara checked within five or six thousand cubic feet?

A. That would be a result inconsistent with the result that I found when making the computations; and I should want to look into the newer computations, step by step. I should still be in a puzzled state of mind to know where the truth lay.

Q. That is to say accepting our increment, when you said Erie did not contribute anything at all, you mean it did not contribute as much as you thought it should contribute, wasn't that it? You did not mean there was no contribution at all?

A. My recollection is that comparing the gagings during the summer season—

Q. About 7,000 cubic feet, wasn't it?

A. It is very small. It is almost no flow at all from Erie, and I cannot believe that.

Q. That is assuming of course that the St. Clair increment is correct?

A. Yes, but so far as—

Q. The St. Clair volume of discharge I mean?

A. So far as I could judge from reading the description of the methods, it seemed to me that they had better conditions for accurate measurement at St. Clair and probably also at the St. Lawrence than they had at the Niagara. That is it is entirely beyond a possibility to find out just how much disturbed conditions are there at the Bridge Station, and at the station 1,200 feet below the bridge, except we know they must be very much disturbed.

Q. You have made no attempt have you in this case to derive an increment for the St. Clair river, using all of the observations except those which in your opinion show some abnormal condition, and would be rejected by students on that ground, and giving to each observation the same weight, and not referring the observation to a gage reading in which there is included the element of this day preceding a group of observations?

A. No, I have not gone into that.

Q. I wanted to know whether you had made any independ-

ent study of the St. Clair measurements, with a view to deriving an increment from those observations, on the theory that that was the river which had been measured the more accurately?

A. No, not by plotting the observations, and attempting to deduce an increment.

Q. Or by making any independent study other than for the purpose of determining what observations in your judgment should be rejected?

A. No independent study. I reviewed Mr. Williams' computations.

Q. But you did not take up each particular observation which had been discarded or the groups that had been arranged?

A. No, only in a general way.

Q. With a view to determining whether they had been done properly or not?

A. No, not in detail.

Q. Now in this study of the relation of the lakes, so to speak, to each other—I think you know what I mean—in the equation which is used as expressing the relation between Lakes Michigan, Huron and Lake Erie, in view of this change of regimen which you say took place along about 1890, would it be proper to include the observations which had been made prior to 1890; I mean when you check, when you are trying to check Niagara with the St. Clair, should you include the observations prior to 1890, on the St. Clair?

A. I think it would be proper to consider it. I do not know without further study just how much weight I would give to it.

Q. If, as a matter of fact there was a change of regimen in the St. Clair river from 20 to 24,000 cubic feet per second, which occurred along about 1889 to 1890, and you were making a study of the discharges of the rivers and conditions in the lakes for the purpose of determining whether your St. Clair observations checked with your Niagara observations, you would not want to take into consideration any measurements that had been made in the St. Clair prior to that period of 1889, 1890, would you, any discharge observations made prior to that time?

A. It is proper to take them into consideration, but one should not use an equation for computing flow prior to the change which was derived from current meter measurements made after the change, if that is what you mean.

Q. That is what I have in mind?
A. Yes.
Q. And any consideration which was given to any one of those observations, if the comparison was to be made with conditions after 1889 and '90 would have to be corrected by the amount of the assumed change?
A. It should be corrected, yes.

Recess to 3:00 P. M.

After recess 3:00 P. M.

JOHN R. FREEMAN, resumed:

Mr. Wilkerson: Mr. Shenehon has a statement to make about that table that we were discussing here this morning. Of course both Mr. Shenehon and Mr. Williams are witnesses in this case, and what they say about this case is in the record as their testimony.

I wish Mr. Shenehon you would take this Exhibit N, for identification, shown to Mr. Freeman this morning, and as to which some question was made by Mr. Williams with reference to the double inclusion of the discharge through the Erie and Welland canals. That was something suggested by Mr. Williams. Have you any statement to make about that, Mr. Shenehon?

Mr. Shenehon: I have checked up the table Exhibit N, and find that the correction for additional flow for the Erie and Welland canals was not duplicated in the years prior to 1898, as suggested. The discrepancy between the discharge of the Niagara river as derived by Mr. Stearns and myself is due to the fact that he referred his discharges to the elevations of Lake Erie as given in the 1910 Report of the International Waterways Commission, while I referred mine directly to the records of the United States Lake Survey. I may add that the International Waterways Commission took the data from the same source, and evidently applied a correction of .1 to it; that is added .1 to it.

Mr. Williams: I think it would be proper to read into the record the statement at the end of the table in the International Waterways Report; also the statement you just read from the foot of your table.

Mr. Shenehon: I read from page 94 Table 2 of the Report of the International Waterways Commission on the regulation of Lake Erie, 1910, note B, B, referring to the observa-

tions from 1888 to 1898, inclusive. The note is as follows: "Derived from U. S. Lake Survey Tables by subtracting .1 foot from records there given."

I refer now to a blueprint giving the monthly mean elevations of Lake Erie at Buffalo, New York, this being one of the records of United States Lake Survey.

Mr. Adcock: Has that been offered in evidence?

Mr. Williams: No, it is not in evidence. It was supposed by Mr. Shenehon to have been offered, but I think he is satisfied now that it was not. I have not seen it.

Mr. Shenehon: The note at the bottom of that table reading:

"The water level records for Buffalo gage previous to March, 1887, were destroyed by fire. From March, 1887, to February, 1899, inclusive, are reduced from tri-daily station gage readings taken at Erie basin. The relation of the elevations of the gage and reference bench marks is not definitely known during this period, and the water levels may be in error in consequence; but probably not to exceed .2 foot.

From March 1899 to date, the monthly means are reduced from the records of the self registering gage located on the Buffalo breakwater. This has been kept carefully referenced to the bench marks." Is that sufficient, Mr. Williams?

Mr. Williams: Yes.

Mr. Adcock: Have we a copy of the document you read from?

Mr. Shenehon: We will furnish you one.

Mr. Wilkerson: Have enough copies made and have it marked Government's Exhibit HH October 14, 1913. Enough copies will be prepared for the record and for counsel.

Re-direct Examination by Mr. Adcock.

Q. Are you aware that Mr. Williams corrected the tables appearing in Williams' Exhibit 34 so as to eliminate the observations made while the Niagara river was affected with ice, that is certain eight or ten observations; and that he also made corrections so as to include in his computation of 1907 and 1908, observations on the Niagara river, and that the elimination of the observations mentioned during the ice period, and the use of the 1907 and 1908 observations did not make any material difference in the result, were you aware of that during the cross-examination?

A. No, I think not. Mr. Williams has told me, I think it was since the cross-examination, that he had.

Q. Mr. Wilkerson asked you as to the effect of certain dredgings at certain points in the St. Clair river, and of Lake St. Clair and the Detroit river. There are certain other points where dredging was done that he did not mention. Did those other points have any effect, in your opinion, in increasing the discharge capacity of that outlet?

A. I think they did; that they would have more material effect than those which we discussed on examination of the charts; particularly in the vicinity of Ballard's Reef, as I remember it.

Q. And that would have a tendency, in your opinion, to change the relation of the levels of Huron to those of Erie?

A. I believe that it would.

Q. So as to lower Huron as compared with Erie?

A. Yes.

Mr. Adcock: I think that is all.

Re-cross Examination by Mr. Wilkerson.

Q. Did I understand you to say that you had seen computations made by Mr. Williams in which the 1907 and 1908 Niagara observations were included?

A. No, I have not seen them.

Q. You saw the computation in which the winter observations had been crossed out?

A. That is my recollection.

Q. And that was the computation which you had in mind when you said you understood that the crossing out of those winter observations made no material difference?

A. Yes.

Q. You are not to be understood as having said that the computation included the 1907 and 1908 observations?

A. Not the original one which I saw.

Q. Where around Ballard's Reef was this dredging which you think had considerable to do with changing the discharge of the river

A. Well all along in that vicinity. It would include the excavation made near the Lime Kiln Crossing, too. But as I recall, it was more particularly above the Lime Kiln.

Q. I rather gathered from what you said yesterday that

you did not think that the dredging at the Lime Kiln Crossing had much to do with the changing of the regimen?

A. Not so much as the natural scour, but I think that all that dredging has had some effect.

Q. In what year do you understand was the dredging around Ballard's Reef which produced this effect?

A. The table showing the dredging done in different years, which I understand is already in evidence in this case, and of which I had a copy at the time I was preparing my report, shows that the excavation directly at Ballard's Reef began in the year 1895, and continued until the year 1903; and that the dredging immediately down stream from that, in the first opening of the Lime Kiln Cut, began in a small way as far back as 1877, and continued irregularly for nearly ten years until 1891, and then was resumed again actively in 1900 and progressed from that time steadily until 1908.

Now there was other dredging done along at different times, which may have affected the outflow to some amount, at the outlet of the Black river. That was done at various times; a little done in 1873 to 1877; then again in 1889 to 1892; then a little in 1898; then a little in 1903.

I did not consider that that Black river dredging had produced any important permanent effect, but it may have in some small degree contributed to the general effect. That is, from what information I could get, I believe that the natural scour which was induced, probably mainly in the great ice gorge which I think occurred in 1901 and in other ice gorges in other years, that that has produced more effect on the lowering of the level of Huron than that which has been produced by the dredging. But I think that both have contributed and that the dredging has without doubt been one cause of the lowering. Just how it should be divided between the two, how the lowering should be divided between the effect of natural scour and the effect of dredging, I would not attempt to estimate.

Q. Are you prepared to say as the result of your examination of this subject that the extent of that lowering has been more than four or five inches?

A. Yes, the total of the lowering I believe to have been decidedly more than that; somewhere between six inches and a foot. Now as to how much of it came from the dredging I don't know; only a part, and probably less than half, I would say.

Q. I thought I got the figure this morning .3 of a foot?

A. No, that was from the diagram which you showed me. I said that taking that diagram which you put before me and attempting to deduce it by those very incomplete observations would indicate that there had been a lowering of about .3 of a foot. But I have just been speaking of my own conclusions resulting from studying this matter last February and March.

Q. I forgot to show you an exhibit this morning, being the exhibit in which the Niagara observations are all plotted, and in which the increment of 21,900 and the increment of 34,-000 are drawn with reference to those observations. Assuming that those lines are drawn accurately, as a student of observations of this character, would you not say that the line 21,900 agrees, or accords more nearly with the trend of those observations than the line 34,000?

A. It so appears from this diagram.

Q. I am assuming that they are accurately plotted, and that the lines are accurately drawn?

A. And that the observations are entitled to equal weight.

Q. Yes. And I think that is your view about the weight of the observations, unless you find an observation that was taken under abnormal circumstances?

A. Yes, other things being equal, I would give them equal weight.

Further Re-direct Examination by Mr. Adcock.

Q. Referring to that diagram Mr. Freeman that has just been shown you, as I understand it you disregard the Niagara gagings or observations there do you not, entirely, for the reasons that you stated this morning; that is they are out of harmony with the other physical conditions; that you do not consider that they harmonize with the gagings in the other rivers.

A. They are not in complete harmony, but still they are not to be disregarded by any means, and so far as I know they give the best means—the only means that we have of determining the increment in a discharge equation at the outlet of Lake Erie.

Depositions in the above entitled cause taken pursuant to stipulation of counsel for respective parties, before the Commissioner, statutory notice being duly waived, at Ann Arbor, Michigan, on July 15, 1913.

Appearances:

Mr. James H. Wilkerson, representing the Government.

Mr. Edmund D. Adcock, and

Mr. Alfred S. Austrian, representing the Sanitary District.

All objections to questions, answers and exhibits shall be considered as having been made, except as to questions involving form, and secondary evidence.

HERBERT CHARLES SADLER, a witness called on behalf of the Sanitary District was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your full name, residence and place of business?

A. My name is Herbert Charles Sadler, place of residence Ann Arbor, Michigan; place of business same.

Q. What is your business?

A. I am Professor of Naval Architecture and Marine Engineering, at the University of Michigan.

Q. How long have you been connected with the University of Michigan?

A. Since 1900.

Q. Will you state your early training and experience, practice as a Naval Architect?

A. I was educated at Dulwich College, England, and at Glasgow University, Scotland. I graduated from Glasgow University with a degree of Bachelor of Science and Engineering, in 1893.

I received the degree of Doctor of Science from the same University in 1902.

From 1890 to 1896, I was engaged in practical ship building on the Clyde, and served an apprenticeship at all branches of the business.

From 1896 to 1900, I was Assistant Professor of Naval

Architecture and Marine Engineering at Glasgow University, and during that time was associated with Professor Biles in a large and varied consulting practice.

From 1900 to date, I have been Professor of Naval Architecture at the University of Michigan.

In 1901 and again in 1904, I was appraiser for the vessel properties in connection with the Michigan Railroad appraisal. I also appraised the vessels owned by the Duluth, South Shore & Atlantic, in 1912. I was one of the consulting naval architects for the City of New York in connection with the municipal ferries.

I have acted as consulting naval architect to the Great Lakes Engineering Works, in connection with the designing and construction of lake vessels. The Great Lakes Engineering Works have one of the largest yards on the Great Lakes. My connection with this firm extends over a period of 10 years, and has covered work in connection with the large type of lake freighers, and also with the Welland canal type.

Among the larger vessels, were such vessels as the Cole, and Shenango. I have also conducted experiments in connection with the tunnel under the Detroit river for the Michigan Central Railroad Company.

For the last two years have acted as Consulting Naval Expert to the Tow Boat Board of United States Army Engineers Corps; in connection with the development of river vessels and barges. The above board consists of Lieutenant Colonel Lansing H. Beach, Major Charles Keller, Colonel Charles Potter and Colonel Newcomber.

I also acted as Consulting Naval Architect for the White Star Line of Detroit, which is engaged in passenger business on the Great Lakes; for the Detroit and Cleveland Navigation Company, and for the Hudson River Day Line, New York.

While you were connected with Professor Biles from 1896 to 1900, what particular work did you perform or were you connected with, in this practice?

A. The practice included the preparation of designs for all classes of vessels; principally those of the London Southwestern Railway, and the American & Red Star Line.

Q. What business were they engaged in?

A. In the cross channel business, and the American Red Star Line in the Trans-Atlantic business.

Q. Since you have been connected with the University of Michigan, what has your work covered?

A. My work has been, first, in connection with the courses

of naval architecture and marine engineering, in which the theory of practice of ship and engine designing is involved.

I have also designed and installed the apparatus for the experimental tank, which is one of the two in the country, and in this connection have been engaged in general research work with ship's forms.

Q. Will you just describe in a general way the tank and its purposes?

A. The naval tank is a large tank 300 feet long, 22 feet wide and 10 feet deep. Its purpose is to enable us to test the resistence and other qualities of vessel's forms. In connection with the tank, there is suitable machinery for making ship models, and cutting them accurately to drawings. After the model is prepared it is placed in the water and attached to a suitable dynamometer, which is mounted on a traveling car. This car may be dragged at any desired speed, and the resistence of the model recorded at any speed.

Q. Electrically operated is it?

A. Electrically operated. In this way we can determine the resistence of the model for any speed, and from that calculate the power required to drive a full sized vessel at corresponding speed.

Q. Is the naval tank that you have just described used only in connection with the University of Michigan work there?

A. It is also available for the solution of actual problems occurring in practice. And we have developed and carried out a series of investigations in the Great Lakes Engineering Works, in connection with the most economical design of vessel for the large freighter type, and also for the Welland canal size.

Q. What is the business of the Great Lakes Engineering Company?

A. They are ship builders, engineers.

Q. When you speak of freighters, you refer to the large freighters used on the Great Lakes?

A. On the Great Lakes.

Q. And designed to be used there?

A. Yes.

Q. You have spoken of the Welland canal type of boat. Can you describe that type?

A. That type of vessel is limited by the size of the Welland canal locks, and in general they run about 250 feet long and 42 feet wide.

Q. And what is the depth of draft of the boat?

A. About 14 feet.

Q. Are you familiar with the design and draft of boats used on Lake Ontario?

A. Not particularly.

Q. Have you been engaged as consulting naval architect since your connection with the University of Michigan, outside of your regular work there?

A. Practically since 1900.

Q. Are you familiar with the classes of boats that are in passenger and the various freight carrying trades on the Great Lakes?

A. Yes, sir.

Q. Do you know about how large the tonnage is of freight per year, of all kinds on the Great Lakes, exclusive of package freight? I am referring to Lake Superior, Huron, Michigan, Erie freight that is carried through the St. Mary's Falls Ship canal and the St. Clair and Detroit rivers.

Mr. Wilkerson: This answer, I assume, is based on some report?

Mr. Adcock: Yes.

Mr. Wilkerson: Not on his own knowledge.

Mr. Adcock: No.

Mr. Wilkerson: If you are referring to some report, specify the report to which you refer and point out such portions as you deem pertinent from your standpoint, and we will call attention to such other portions as we deem necessary.

A. Referring to the St. Mary's Falls canal, Michigan, Statistical Report for 1912, the total traffic is given at 72,472,676.

Q. What is the ore tonnage?

A. The ore tonnage as far as I remember was last year between forty and fifty million tons.

Mr. Wilkerson: Is that for the year 1912, that is from January to January; January 1, 1912, to January 1, 1913?

A. Yes, the season.

Mr. Adcock: I presume it is the season of navigation.

Q. What is the tonnage of coal and wheat?

A. The coal tonnage is about 14,900,000; and the wheat about 5,220,000.

Q. What are the sizes and dimensions of different classes of boats that are engaged in the heavy freight business, ore and coal and wheat trade?

A. They run from in the neighborhood of 400 feet to 600 and over, slightly over in length.

Q. Are they divided, those you have mentioned there, divided into three classes, approximately those 440 feet in length, and about 550 feet and 600 feet and over?

A. Yes.

Q. What is the beam and draft of the different classes that you have mentioned, the dimensions of them?

A. The dimensions would be about 440 by 52 by 28 feet in depth. The 550 would class 550 by 56 by 31, and 605 by 58 by 32.

Q. How many boats are there of those different classes in service now, or were in service last year on the lakes?

A. This is quoting: Of the smaller ones 151; the 500-foot class, 93; and the 600-foot class, 73.

Q. You are familiar with the design of these different boats as a class, are you?

A. Yes.

Q. Do you know what depth the 440-foot class are designed to be loaded to?

A. 19 feet.

Q. And the 550-foot class?

A. 19 feet in general.

Q. And the 600

A. 19 feet in general also.

Q. May those be loaded deeper?

A. It might be possible to load the larger types, the 550 and the 600-foot classes somewhat deeper.

Q. Have you considered the question as to whether the vessels that were of the 550 and 605-foot class could be designed so as to offset a decrease in the depth of water of say 1, 2, 3, 4, 5 or 6 inches, so as not to detract from their efficiency materially?

A. I have.

Q. And would they carry approximately the same amount of tonnage, same material, the design that you have spoken of?

A. Yes.

Q. Will you state what investigations you have made and what conclusions you have reached in regard to that, in regard to the subject matter of the last question and answer?

A. I have made calculations showing the effect of the loss of draft of 1, 2, 3, 4 inches, etc., for the following types of vessels:

1st. A vessel 440 by 52 by 28.

2nd. 550 by 56 by 31, and

3rd. 605 by 58 by 32.

Taking the smallest class first, the loss in capacity for one inch draft would be about 55 tons. In order to compensate for this loss, the vessel would have to be increased in length about 2.1 feet. The increased cost of the vessel would be about $1,000, and the interest and depreciation $100. For two inches loss of draft and three inches loss of draft the figures would be in the same proportion, or a loss in capacity for three inches would be 165 tons; the increase in length to enable the vessel to carry the same cargo as before 6.3 feet; the increased cost of the vessel about $3,000, and the interest and depreciation about $300.

Mr. Wilkerson: Q. That figure of $3,000, is that the difference between the cost of constructing two new boats, one of one type and one of the other, or the cost of making an old boat over?

A. That would be additional cost due to adding 6.3 feet to the original boat.

Q. That is if you constructed a new boat?

A. A new boat.

Q. A new boat of the kind which you described as being designed to offset the effect?

A. Yes.

Q. Of the loss in capacity?

A. Yes.

Mr. Adcock: Now if you will, proceed with the answer to the question before you were interrupted.

A. For the 550-foot class, the loss in capacity for one inch would be 70 tons, the increase in length required to equal this loss 2.9 feet; the increase in cost of the vessel $1,700; the interest and depreciation $170. The figures would be proportional for 2, 3 or 4 inches. And for 3 inches loss of draft, the loss in capacity would be 210 tons, the increased length necessary to compensate for this 8.7 feet; the increase in cost of vessel, $5,100; the interest and depreciation $510.

For the 605-foot class, the loss in capacity for one inch would be 81 tons; increase in length to equal this loss 3.1 feet; increased cost of vessel about $1,800; the interest and depreciation $180.

The figures would be proportional for 2, 3 and 4 inches loss of draft. And for three inches, the loss of capacity is 243 tons; the increase in length 9.3 feet; the increase in cost of vessel $5,400; the interest and depreciation $540.

Q. Now you have spoken of these three classes. Do those

classes of vessels carry practically all of the coal and wheat and ore on the Great Lakes?

A. They carry about 70 per cent. of the total.

Q. What proportion of the ore, wheat and coal is carried by the 440-foot class or vessels smaller?

A. About 48 per cent.

Q. You have stated I believe the proportion that was carried by the 550-foot class and the 600-foot class I believe, haven't you? If you have not will you state it?

A. The 550-foot class carry about 26 per cent. of the total, and the 600-foot class about the same, 26 per cent.

Q. About how many tons is that all together?

A. About 18,800,000 for each two larger classes.

Q. About 37,000,000 all together?

A. Yes, sir.

Q. Are carried by those two classes per year?

A. Yes.

Q. A boat designed as you have suggested to offset for loss of draft of 1 inch, 2 inches, 3 inches, 4 inches 5 inches and so forth, would it cost any more to operate that boat than a boat designed to carry the same tonnage with the deeper draft?

A. No.

Q. Now you have spoken of the increase in cost of different designs of vessels there, those three classes that you have mentioned, and you have spoken also of the increase in cost for one inch and for three inches. Would that be in the same proportion up to 6 or 7 or 8 inches?

A. Yes.

Q. You have spoken of the draft of a boat and the depth, and also the registered tonnage and dead weight tonnage and so forth. Will you explain those different terms?

A. The depth of a boat is the distance from the keel to the deck. The registered tonnage of a vessel is the figure obtained by calculating the internal capacity of the vessel in cubic feet and dividing by 100. In other words the unit for registered tonnage is 100 cubic feet of internal capacity.

The dead weight tonnage is the actual number of tons of cargo that the vessel would carry at a given draft.

Q. Then you have spoken of the draft of a boat also? What do you mean by that term?

A. The draft is the actual amount of water that the vessel draws measured from the bottom of the keel. I might add

that if a vessel is out of trim, by the term draft in connection with dead weight, we generally mean the mean draft.

Q. What do you mean by the term "free board?"

A. Free board is the amount of side of a vessel from the water line to the deck.

Q. What is that in a boat of these given classes that you speak of?

A. That is about nine feet in the 440-foot class.

Mr. Wilkerson: Q. It is the difference between 19 and those figures?

A. Yes; and about 13 feet in the larger classes.

Mr. Adcock: Q. Do you know how many boats of the three different classes you have spoken of have been added in the last year to the service on the lakes?

A. 20 of the 400-foot class and 6 of the 500-foot class and 14 of the larger type.

Q. When you say 400-foot class, you mean boats of those lengths, 400 and 500 and over and 600?

A. Between five and six hundred.

Q. That is over to the next class?

A. Yes. That was in the last year?

Q. Yes.

A. Yes.

Q. Do you know how many of the 400-foot class have been built and put in service in the last 13 years or so, since 1899?

A. All except 41.

Q. All except 41. That would be 110?

A. 110.

Q. How many of the 500-foot class and 600-foot class have been built and put in service since 1899, or the last 13 years?

A. Practically all of them.

Q. Were there any in service prior to 1900 of those two classes, 500 and 600 feet?

A. Referring to the St. Mary's Falls Canal Report for 1899, I find that there were no vessels over 500 feet in service.

Referring to the 1903 report, the maximum length given is 498 feet.

Q. You have calculated the cost of building a boat to take care of three inches less in depth of water, and stated it to be I believe $5,100, and that the interest and depreciation would be about $510. Have you made any calculations for the purpose of capitalizing the $510 interest and depreciation?

A. Yes.

Q. What is that?

A. At 5 per cent. capitalization this would be about $10,000.

Q. So that the total loss then would be $15,100?

A. Yes.

Q. Including the $5,100 actual cost of building. Then, have you made any calculation as to the total loss on that class of boat, being 93 in all, for the three inches loss in depth?

A. Yes.

Q. State what that is?

A. For the different classes?

Q. No, for the 500-foot class and over, up to 600?

A. For 93 vessels, this would be $1,404,300.

Q. Have you made the same calculations in this respect with reference to the 600-foot class?

A. Yes.

Q. Will you state what the results are?

A. The interest and depreciation capitalized at 5 per cent. would amount to about $11,000, or for the 73 vessels in this class $1,197,200.

Q. And that would be in the same proportion as to four or five or six inches, or one or two inches?

A. Yes, sir.

Mr. Wilkerson: All your capitalization figures are on the basis of three inches loss?

A. Three inches.

Mr. Adcock: Q. The two classes that you have mentioned, the 500-foot and the 600-foot class are the largest draft boats in the trade on the lakes, are they not?

A. Yes.

Q. And they are the only ones that may be capable of being loaded, that is are designed to be loaded more than 19 feet?

A. Yes.

Q. Have you made any calculation, leaving out any question of design of the boats, or change of design, have you made any calculation as to the loss per year to the lake commerce of the loss in depth of water of 1, 2, 3, 4, 5 and 6 inches, as to the two classes of boats, 500 and 600-foot class?

A. Yes, I have.

Q. Have you read the record showing the testimony of Mr. Coulby and Mr. Livingstone, who were witnesses for the complainant in this case?

A. I have.

Q. From that testimony and the facts presented by them and from your experience in calculations made, will you state your conclusions as to the losses to lake commerce from the loss of depth of water of 1, 2, 3, 4, 5, 6 inches and so forth, and the method that you have pursued in arriving at the results?

A. The following figures were based upon the steamers Rogers and Corey.

Q. They represent what classes of boats?

A. They represent about the 600 and 550-foot classes.

Q. Respectively?

A. Respectively.

Q. You may proceed with the answer to the previous question.

A. As a basis for the calculations, a change of draft of two feet was chosen. Considering the Steamer Rogers, first, as representing the larger class, the displacement, on a draft of 19 feet, is 15,800 tons. The tons per inch, 81; the cargo carried per annum 323,000; the number of trips, 29; operating expenses $127,000.

Q. That is those figures were obtained I believe from Mr. Coulby's testimony and Mr. Livingstone's?

A. Mr. Coulby's testimony.

Q. Mr. Coulby's testimony.

A. If loaded to two feet deeper, the increase in cargo carried would be 1,944 tons per trip; therefore for 29 trips, it would be 56,400 tons. Owing to the extra draft, the vessel would require about 150 horse power more than at present for the same speed. This would involve an expenditure of about $870 per annum. The increase in expenses, due to unloading the extra amount of cargo due to the two feet extra draft, at 20 cents a ton, is equal to $11,280. The total increase in expenses is therefore $12,150.

From the original figures as given by Mr. Coulby, the cost per ton works out at 39.4 cents. With the draft increased two feet, the cost per ton would be from the above figures 36.7 cents.

Dealing now with the Steamer Corey, as representing the 550-foot class, the displacement at 19 feet is 14,300 tons; the tons per inch 73; the amount of cargo carried per annum 295,802 tons; the number of trips 29; the operating expenses $123,404. When loaded to 2 feet deeper draft, the increase in cargo would be 1,750 tons per trip, or the increase in cargo

per annum for 29 trips 50,700 tons. The increase in cost of coal would be approximately the same as for the Rogers, or $870. The increased expenses for unloading, $10,140 or a total of $11,010.

For the figures as originally given, the cost per ton works out at 41.7 cents.

Q. That is according to the complainant's testimony?

A. Yes. With the draft increased 2 feet, the cost per ton is 38.8 cents. The difference due to 2 feet extra draft in the case of the Rogers was 2.7 cents per ton, and 2.9 cents in the case of the Corey; or an average of say 2.8 cents per ton for this class of vessel. This saving in cost would be proportional for each inch of draft, or say .116 cent per ton per inch.

For a vessel of the size of the Rogers, with an average of 11,100 tons per trip, the cargo carried and the effect upon the cost have been estimated for 15, 20 and 25 trips per annum, corresponding to an increase in draft of 1, 2, 3, 4 inches and so forth.

For an increase in draft of one inch, the increase in cargo would be 81 tons per trip, and therefore for 15 trips would be 1,215 tons, for 20 trips 1,620, and for 25 trips 2,025 tons. The total cargo carried for 15 trips would be 167,715; for 20 trips 223,620 tons, for 25 trips 279,525 tons.

For a loss of draft of one inch, the increased cost would be .116 cent per ton, or an increased cost of $194 for 15 trips, $259 for 20 trips and $324 for 25 trips. For 2, 3, 4 inches, etc., the figures would be in the same proportion, or for 3 inches difference of draft, the increase in cost per annum would be $588 for 15 trips, $790 for 20 trips and $987 for 25 trips.

In the case of the Corey, the increase in cargo for one inch for 15 trips would be 1,095 tons; for 20 trips 1,460 and for 25 trips 1,825 tons.

The total cargo carried per annum, for 15 trips would be 154,095 tons; for 20 trips 205,460; for 25 trips 256,825 tons.

Q. That is with the increase of one inch?

A. Increase of one inch. The increased cost for one inch decrease in draft for 15 trips would be $179; for 20 trips $238 and for 25 trips $297. For 3 inches, the figures would be $537 for 15 trips; $714 for 20 trips, and $891 for 25 trips.

For the 73 vessels of the Rogers type, the increased cost per annum for one inch draft—

Q. Loss?

A. Loss would be $14,160 for 15 trips; $18,900 for 20 trips and $23,650 for 25 trips. For three inches loss of draft, the

figures would be $42,480 for 15 trips; $56,700 for 20 trips and $70,950 for 25 trips.

For the 93 vessels of the Corey type, the figures would be, for 15 trips, $16,650; for 20 trips, $22,130; for 25 trips, $27,-620. For three inches decreased draft, the increased cost would be for 15 trips $49,950; for 20 trips, $66,390; for 25 trips, $82,860.

Capitalizing the above sums for the three inch difference of draft and for the 166 vessels of the two classes, the figures are as follows:

For 15 trips, $1,848,600; for 20 trips, $2,461,800; for 25 trips, $3,076,200.

Q. On the basis of the amount of tonnage actually carried per year by these 166 vessels, have you made any calculations as to the loss, possible loss?

A. For the 37,000,000 tons—

Q. Your answer is yes?

A. Yes.

Q. I will ask you to state the result, what your calculations were and the results?

A. For the 37,000,000 tons approximately carried by these two classes, at .116 cent for one inch the loss would be $42,-920.

Q. And for three inches would be how much?

A. And for three inches would be three times that or $128,-760.

Q. Capitalized at 5 per cent. what does that equal?

A. $2,575,200.

Q. Now the unloading charge and the other figures that you have used there, where did you obtain them?

A. From Mr. Livingstone's testimony.

Q. How deep could you load the boats of the 600 and 500 foot class? Take the 600 foot first. How deep may you load, with due regard to the safety of operation and so forth?

A. So far as free board is concerned, the vessels could probably load to 23 feet.

Q. That is the 600 foot class?

A. The 600 foot class, and retain the same free board as the 400 foot boats. So far as strength is concerned, it might be possible to increase the present stresses about 10 per cent., which would mean that the vessels could load to 21 feet.

Q. That is the maximum load?

A. Yes.

Q. Maximum depth that they should load?

A. Yes.

Q. That is of the 600 foot class?

A. Yes.

Q. With reference to the 500 foot class what would you say?

A. The figure would be approximately the same.

Q. Did you have anything to do with the design and construction of the Cole and Shenango which are boats, I believe you stated, in the larger freighter class here?

A. Yes, I carried out a series of experiments upon those vessels to determine their best shape.

Q. You are familiar with the cross section designs of those boats I believe?

A. Yes.

Q. And the dimensions and the strength?

A. Mid-ship section.

Q. Mid-ship section?

A. Yes.

Q. Do you know anything about what those boats have done, either one of them in the service in the last year or so?

A. I understand the Shenango carried the largest cargo on the lakes, largest ton mileage on the lakes.

Q. When you say you understand, you refer to the report of St. Marys Falls Ship Canal of 1912?

A. Yes.

Q. And that boat is of the 600 foot class, as I understand it?

A. Yes.

Q. You stated that these boats of the 500 and 600 foot class were designed to be loaded to a depth or draft of 19 feet, and you also stated that by increasing the stress say ten per cent, on the larger boats, the boats of larger class, they might be loaded 21 feet. In your opinion what would be the greatest depth of draft, of loading the vessels of the two classes consistent with safety of operation and good practice?

A. I feel that I would not like to advise anyone to increase the stresses more than 10 per cent. over those at present; and therefore not to load deeper than 21 feet.

Mr. Adcock: That is all.

Recess to 1:30 P. M.

After Recess 1: 30 P. M.

HERBERT CHARLES SADLER, resumed the stand and testified further as follows:

Cross-Examination by Mr. Wilkerson.

Q. You have grouped these vessels into three classes, Professor; the vessels with dimensions 550 by 56 by 30 and 605 by 58 by 32. How long did I understand you to say it was since the first one of the 550 foot vessels was constructed?

A. It was 500 feet I think.

Q. Have you anything before you that shows just the facts as to the time when those larger vessels came into use on the lakes?

A. In 1903 the maximum length was 498 feet.

Q. That is to say in 1903, there was no vessel in use on the lakes, the length of which was more than 500 feet?

A. No.

Q. Is that right?

A. That is right, yes.

Q. Now have you tables before you from which you can state, or if you haven't the tables can you state from recollection approximately the facts as to the number of vessels of these classes I have referred to, which have come into use during each of the years since 1893?

A. There was one vessel of 560 feet in 1904, so practically all of them have come in since 1903. And according to the 1912 report, there were 93 vessels of about the 550 foot class and 68 of the vessels about 605; five over 600.

Q. When did the first one of those of the length of more than 600 feet come into use?

A. In 1907 there were two of them.

Q. That is to say in 1907 there were two vessels longer than 600 feet each?

A. Yes, 605.

Q. Have you anything there before you which shows how many of them were built in 1908, 1909, 1910 and 1911?

A. There were two in 1908, three in 1909, three in 1910, and four in 1911.

Q. And the remainder in 1912?

A. Five in 1912.

Q. That does not account for all of the 73?

A. That is from 550 to 600.

Q. As I recall your classification, you had 73 of one type. What was that type in which there were 73?
A. Of the roughly the 600 foot type.
Q. That is the type I am speaking of?
A. Yes.
Q. You had 93, roughly, of the 550 foot type?
A. Yes.
Q. I suppose we can get the exact figures?
A. Yes.
Q. What I understand the fact to be—I want to know if I am in error about it—is that most of those have been put into service within the last few years?
A. Yes.
Q. Those two types?
A. Those two types, yes.
Q. And those have been coming into use, have been increasing each year?
A. Yes.
Q. That is more in 1912 than 1911?
A. Yes.
Q More in 1911 than in 1910?
A. Yes.
Q. Now in forming your opinion of the injury to navigation in this case, which would be produced by diminishing the depth of the channels at the critical points, did you make any study of these figures for the purpose of arriving at a conclusion as to how many of the vessels of these two types, having in mind the number that have come into use already, and the probabilities of the case according to the law that you might arrive at, how many of the vessels of those two types would be in use within the next ten years? Did you give any weight to that?
A. No, I didn't make any estimate of that at all.
Q. Didn't make any estimate of that kind at all. But you have no doubt but that the tendency is towards the use of the vessels of the larger type, and that within the next period of ten years or twenty years, there will be very many more vessels of those two types in use than are in use now, have you?
A. Yes, from the 550 to the 600 foot class, will probably be the—
Q. That would be your judgment based upon your knowledge of the lake commerce?
A. Yes.

Q. And your experience?

A. Yes.

Q. Having come in contact with it and looking at the tendency in the building of vessels to-day?

A. Yes.

Q. That there will be a great many more of those large vessels in use?

A. Probably, yes.

Q. So that your figures which you have given us based upon the number of vessels in use in 1912, in order to get at the future damage, would have to be increased so as to correspond with the number of the vessels of the larger type which were actually in use at the particular time, wouldn't it?

A. Yes, certainly.

Q. So that if there were two or three times as many vessels of those types in use four or five years from now, your figures would have to be multiplied by 2 or 3 or 4 as the case might be?

A. Certainly.

Q. Now you spoke about the vessels of the Welland Canal type, and those are vessels which have a draft of 14 feet maximum. That is due to the fact that you cannot get a vessel of a larger draft through the canal?

A. Yes.

Q. Now with respect to vessels which are used in that kind of commerce, the tendency in vessel building has been to build right up to the limit of the canal, has it not?

A. Yes.

Q. That is they will build vessels as large as the capacity of the canal will permit to be used?

A. Certainly.

Q. That has been true of the other locks, has it not to the extent that the size of those vessels is limited by the locks at the Soo, is that the point?

A. Somewhat; the draft—

Q. The draft at the Soo fixes the limit for the size of vessels which are engaged in the commerce on Superior, Huron and Michigan?

A. Not necessarily.

Mr. Austrian: I do not think you mean the size?

A. You mean length.

Mr. Wilkerson: Q. The draft of the vessels.

A. The loaded draft is fixed by the Soo, as one of the fixed points.

Q. What is that now?

A. About 19 feet.

Q. That is the reason why you say the vessels of too large a type, they may be loaded to a depth of 19 feet only, because of the fact that is the limit?

A. Yes, that is their designed draft.

Q. Now it is in contemplation is it not that the depth there is to be increased?

A. I believe so.

Q. To 24 feet?

A. I don't know the actual figures.

Q. If it were to be increased to 24 feet, that would make possible the use in commerce of the types of vessels which are considerably larger even than those now in use, wouldn't it?

A. Yes, if the rest of the conditions kept pace with it, I mean the harbors.

Q. I mean other conditions being adjusted so as to correspond, you could use in the commerce of the lakes vessels with a draft of 24 feet?

A. Yes.

Q. That would mean that they would be longer, and they would have a great deal larger capacity?

A. Not necessarily longer. They could load them deeper.

Q. They could load them deeper, and they might be longer?

A. That would depend on the conditions of handling and so forth. The length is more dependent on that than on the draft.

Q. With those larger vessels, the effect of a loss of 1 or 2 or 3 inches would be greater proportionately would it not than in the case of smaller vessels?

A. That is vessels, do I understand you ,vessels loaded to a deeper draft?

Q. Yes.

A. No, the effect of one inch, if you kept the other dimensions the same, would be the same.

Q. But if you had a vessel of the larger draft, if you built the way vessels are constructed now, the other dimensions would be increased, would they not?

A. Not necessarily.

Q. Well, not necessarily?

A. No.

Q. But probably; that is to say if you were designing a vessel with a draft of 24 feet, if you followed the ordinary rules, it would be a longer vessel than one with a draft of 21 feet?

A. No, not necessarily.

Q. Of course not necessarily, but as a matter of fact generally speaking, would't you have a longer vessel. You find the vessels of greater draft the longer they are?

A. Not in connection with the lake types, because you gain so much more by increasing the draft than length. It is much less expensive a thing to do. You can put the whole vessel down one inch.

Q. That is why it is very important that you have conditions so that you can have as great a draft as possible?

A. Yes.

Q. In building vessels for the lake trade?

A. Yes.

Q. It is regarded as a matter of considerable importance is it not?

A. Yes.

Q. Now in this first table which you have prepared and about which you have testified, you have given certain figures which indicate the amount which it would be necessary to increase the length of the vessel in order to compensate for the loss in capacity due to the loss of draft. And I notice the first figures have a loss of draft of one inch, you have capacity in tons for vessels of the first class, 55 tons, and an increase in length to equal that loss of 2 feet 1 inch, 2.1 feet?

A. Yes.

Q. Is that computed according to some formula which you have?

A. That was obtained by taking into account the extra weight of structure and the extra displacement needed to be equivalent to that change of 1 inch of draft.

Q. Just how did you do that? Tell me how you got that 2.1 feet there?

A. I estimated the weight per foot of length of each particular size of vessel, and that added to the weight lost due to 1 inch would finally give me a means to find the extra displacement for the total extra weight carried.

Q. What I am trying to get at is, have you the data of your computation here, so that I can follow the figures through

by which you go from the loss of 1 inch of draft to the increase in length of 2.1 feet?

A. No, I haven't those figures here.

Q. Just describe the process as nearly as you can. I want the mathematical process so that if I wanted to check your figures, I would know how.

A. Well, the area of the mid-ship section multiplied by one foot of length would give the extra displacement in cubic feet for 1 foot added length. Now when you add one foot of length, you add one foot of extra structure, so that you do not gain all that displacement due to that extra foot of added length. Now in the case of the vessel cited—what is that table?

Q. These dimensions are 440 by 52 by 28, in your first column.

A. Finally we have to carry 55 tons more in the vessel, and by a process of trial and error, we can determine the exact length that must be added, so that the added displacement will be equal to the 55 tons plus the weight of the structure, so that the net gain in this case due to 2.1 feet is equal to 55 tons.

Q. You have made an estimate of the increase in the cost of the vessel. You have computed, I suppose, the amount of material?

A. Yes.

Q. And computed the value of the material, on what basis?

A. That material would all be put in mid-ships and would be structural steel work, and on a basis of about 3¼ cents a pound, finished material.

Q. On the basis of about 3¼ cents a pound?

A. Yes.

Q. Take vessels of the two types, of the same carrying capacity, but the one with the greater length and the other with the greater draft, what about the resistance in going through the water, which one goes through the more easily?

A. It would be about the same.

Q. No different?

A. No, practically the horse power would be the same for those two vessels.

Q. Within the limits of a foot?

A. Yes.

Q. Two feet? I have an idea you have a little more space on the vessel moving through the water where you have greater length than a vessel of the other type?

A. No.

Q. Certainly under certain limits?

A. A large part of the resistance of vessels of this type at the speed with which they move is surface friction, and the amount of horse power required to overcome that provided great change in length was not made would vary just about as the surface—

Q. I understood you to say a little while ago that the draft was the thing that you would look after; that is draft was preferable to length; it was better to have vessels of greater draft than a long vessel. Just why is that?

A. It is cheaper.

Q. Cheaper to build it?

A. Yes.

Q. And easier to operate? It sits deeper in the water doesn't it, is more stable?

A. Not necessarily, no.

Q. It is deeper in the water?

A. That does not necessarily act as stability.

Q. Generally does, doesn't it?

A. No, sometimes the other way.

Q. Sometimes the other way?

A. Yes.

Q. So it is a matter of cost of construction that makes that difference?

A. To carry a given amount.

Q. In your computation with reference to the Steamer Rogers, a vessel of dimensions 580 by 58 by 32, I notice an item "Increase in expense of unloading at 20 cents." On what basis did you reach that figure, 20 cents?

A. From the figure given by Mr. Livingstone in his testimony.

Q. That is to say that the average expense of unloading a ton of freight is 20 cents?

A. I understand so from—

Q. And this table was made on the assumption that starting out with a given vessel, an annual cargo of 323,000 tons, that if you increased that to 379,400 tons it would cost 20 cents a ton more to handle that freight?

A. To handle the difference.

Q. To handle the difference, yes.

A. It would cost 20 cents a ton to handle—

Q. The difference. It is based on that?

A. Yes.

Q. It is based on that assumption. Take a vessel that has a cargo increased 1944 tons at one trip, you would probably have the same crew, would't you?

A. Yes.

Q. And as a matter of fact having in mind the way in which vessels are operated, it probably would not cost 20 cents a ton more to increase a cargo to 1944 tons, would it?

A. Yes, that is the unloading charge, I understand, charged the ship by the docks for unloading the cargo.

Q. You understand that is a charge made to the ship by the docks?

A. Yes for unloading.

Q. That is a fixed charge, of so much per ton?

A. Yes.

Q. Without any reference at all to the size of the cargo?

A. Yes, I understand so.

Q. And the computation is made on that basis?

A. Yes.

Q. I just wanted to get clearly in mind the basis on which the computation was made?

A. Yes, that is it.

Mr. Adcock: That was the deduction you drew from Mr. Livingstone's testimony wasn't it, and Mr. Coulby's?

Mr. Wilkerson: I wanted to make clear just why that item of 20 cents was put in there?

A. It might be Coulby.

Mr. Wilkerson: I shall be very glad in this connection to have you refer to the portion of the testimony you indicate.

Mr. Williams: I will look it up for you; you can go on.

Mr. Wilkerson: Q. In these computations as to the saving of expense due to the use of boats of larger draft, you had in mind that you had a given quanitiy of freight which was to be moved, and that it would cost a certain amount more to move it in boats of the one class than in boats of the other. That I understand is what you had in mind in preparing those tables, is it not?

A. Not exactly. I took the boat, the Rogers, and the other, and those figures were based on the added amount that that particular vessel could carry, if she could load to a deeper draft.

Q. On the Great Lakes there is a season of navigation isn't there?

A. Yes.

Q. If you have a certain number of boats that are available for use and the amount of cargo that is moved is dependent upon the number of boats which are available, your loss to commerce would be not merely this difference, but it would be the fact that that ore or grain or whatever it is is not moved at all, wouldn't it be?

Mr. Austrian: You must put in another condition there, that you have not sufficient boats to move your commodity that is desired to be moved. You haven't got that in.

Mr. Wilkerson: Now let us just take the case of iron ore.

A. Yes.

Q. You are transporting iron ore from points on Lake Superior to Cleveland, and you have here a vast quantity of ore which may be moved from one place to the other. You have a certain number of boats in the service that are available for use. Now you can load only to a certain depth. If you could load three inches more, you could put in so many tons more of the ore, so that if you are going to figure the real loss under a situation of that kind, you would have to take into account the fact that you have so much ore which might have been moved if you had had the boats, but which was not in fact moved.

Mr. Austrian: You cannot do that—I will put it in the form of an objection if you want—you cannot take that point of view unless you eradicate airships, which may provide a further means of transportation.

A. The point is in the history of transportation that the tonnage has usually kept pace with the demand for it; if anything a little above.

Mr. Wilkerson: Q. Of course they build boats as they are required.

A. As they are required.

Q. Is was just trying to get clearly what your theory has been of this relation of tonnage to navigation. With reference to this transportation, is it a fact that these cargoes are transported as late as December after the insurance has expired; that is that the demand for service of that kind is such that they actually take the risk of engaging in transportation during a month when they cannot get insurance?

A. I understand so. They run. I would rather the ship owners gave evidence on that point.

Q. But that is your understanding?

A. That is my understanding.

Q. Wouldn't that indicate to you that the real loss which

is suffered is the complete loss which results from the fact that so much ore is not transported which otherwise might be transported?

A. Well, there is no doubt that if the lakes were open to navigation all the year around, there would be transportation all the year around.

Q. There would be more transportation?

A. Of course.

Q. They would bring that ore down more rapidly?

A. They would bring it down at the same rate, but if we had the lakes open all the year around, there would certainly be transportation of ore all the year around.

Q. Has the commerce on the lakes increased any definite ratio, or percentage of increase Do you know what the facts are; have you studied that?

A. There has been more or less steady increase.

Q. Has it been rather a fixed increase?

A. It fluctuates from year to year.

Q. Of course, but I mean the general line is upward?

A. The tendency is upward.

Q. Has relation does it to the increase in population?

A. I have not studied that particularly.

Q. You haven't studied that?

A. No.

Q. But in this question of damage to navigation, that is an element that would necessarily have to be taken into consideration to reach any conclusion as to the full damage in the future, isn't it?

A. Probably.

Q. If you were trying to arrive in your own mind at something which would state the full damage, the probable damage to navigation in the future, you would have to give consideration to this study of increase in commerce on the Great Lakes?

A. Well I suppose so, but I have not studied that question at all.

Q. You just simply made an estimate on the basis of the year 1912?

A. Yes.

Q. When you speak of 29 trips, does that mean round trips?

A. Yes, that is according to—

Q. 29 round trips, there would be a cargo each way; those

large boats take ore going down and coal going back usually?

A. Not always, no.

Q. Sometimes?

A. Depends on the state of the trade. If the ore trade is busy, the vessels are very often sent up light.

Q. There would be some loss on the back trips, if the trade was such that the boat could be loaded fuller, which is to be taken into consideration to get the full figure?

A. Yes.

Q. Returning for a minute to the question of the building of vessels, there have been, in connection with the ocean commerce, the tendency has been right along towards the use of larger vessels?

A. Yes.

Q. And so far as the commerce on the lakes is concerned, if there should be ultimately deep waterway navigation, if that plan should be worked out there would be a tendency towards the use on the lakes of vessels very much larger in size than are used now? I am speaking of the general trend of vessel building.

A. Well, I feel personally that vessels much over 600 feet would be rather unwieldly in narrow channels, and for general handling purposes.

Q. But with the larger draft, if the time came when the ocean-going vessels, through the deep waterway project, were brought into the lakes, the movement would be to get as much draft as possible, wouldn't it, to increase the depth of the channels and build vessels of larger draft?

A. To accommodate ocean vessels?

Q. Yes.

A. Yes.

Mr. Austrian: Q. And also widen the channels too, wouldn't it?

A. Yes.

Mr. Wilkerson: With reference to the vessels longer than 600 feet being unwieldy, is that because of the light draft?

A. No, it is due more to the length.

Q. Does the smallness of the draft have anything to do with it; is that a factor?

A. It might even accentuate it in certain places, if the draft were increased, in currents, where there are currents?

Q. You gave us some figures this morning, I think a figure of about two and a half millions of dollars, on a basis of a

certain tonnage, and on the basis of a loss of draft of three inches. For a loss of draft of six inches, that would double, be $5,000,000?

A. Yes, sir.

Q. And for a loss of 10 inches that would be about $8,000,000; 3⅓ times 2½?

A. Yes, sir.

Mr. Austrian: It would be in the ratio?

A. In the same ratio.

Mr. Wilkerson: Your figures were $2,575,200, loss of draft of 3 inches; 6 inches would be $5,150,400; and that was merely on the two classes of vessels, the vessels in the second and third class as you have them classified?

A. Yes.

Q. And on the basis of the number in use in 1912?

A. Yes.

Mr. Austrian: And that loss was capitalized; the amounts you have given?

Mr. Wilkerson: Q. On the basis of 25 trips a season, 20 trips was it?

A. It was not—

Mr. Adcock: We took arbitrarily 15, 20 and 25 trips.

Mr. Wilkerson: Q. On the 25 trips you had a figure of $3,000,000, a little over?

A. Yes, sir.

Mr. Austrian: Q. As I understand it that is the loss capitalized?

Mr. Wilkerson: Yes.

Q. As I understood you to say a moment ago, that did not include the up-cargoes?

A. That is for that amount of cargo moved.

Q. For that amount of cargo moved?

A. Whether it was up or down, those figures would be correct.

Mr. Wilkerson: I think in this connection, we would better have in the record in this case the full report, statistical report, of lake commerce passing through the canal at Sault St. Marie, through Michigan and Ontario, during the season of 1911. That I understand is the document from which you—

Mr. Adcock: No, that is 1912.

The Witness: 1912.

Mr. Austrian: Let us have a further stipulation that all these reports from 1899 to 1912 may be considered in evidence; need not be attached but may be referred to by either

side, with the same force and effect as if incorporated in the record.

Mr. Wilkerson: I think myself it is a document that the court will take judicial notice of, and will take judicial notice of the facts stated. I am perfectly willing that the court should do that.

Mr. Austrian: Take judicial notice of the figures in these reports 1899 to 1912; and everybody may refer to them with the same force and effect as if incorporated in this record.

Mr. Wilkerson: We will stipulate the court may take notice judicially of the figures.

Mr. Austrian: Or any facts or statements therein contained.

Mr. Wilkerson: Q. There is more tonnage through the Detroit river than the Soo, is there not? Look at the report. In the case of the Soo, it is 72,000,000; at the Detroit river it is 78,000,000, as Mr. Shenehon advises me.

A. There is more tonnage through the Detroit river than the Soo.

Q. What is the fact about it?

A. You want the actual figures? There is 72,472,676 tons through the Soo, and 78,671,208 tons passing through the Detroit river.

Mr. Adcock: What does that cover what kind of freight?

A. That is all kinds.

Mr. Austrian: Mr. Wilkerson, I think in view of the fact that you want to get a concrete statement into this record as to the comparative tonnage at the Soo and Detroit river, you ought to also put in the fact, as appears from the St. Marys Fall Canal, Michigan Statistical Report, etc., from which the witness got these figures, that the tonnage at the Detroit river is estimated, and includes a large amount of railroad ferry tonnage, which really is railroad tonnage; and that appears on page 27 of the report in question.

Mr. Wilkerson: Of course whatever appears in this report may go in.

Mr. Austrian: The Soo is accurately computed. The Detroit river is simply estimated, and also as appears on page 27 includes this railroad ferry tonnage, which is simply a convenient means of transporting the cars and the tonnage in the cars on very shallow draft boats used only for that purpose, and really is part of railroad transportation.

Mr. Wilkerson: Q. Have you made any examination of these official tables with a view to ascertaining what the fact

is as to what proportion of the whole commerce of the lakes goes through the Detroit river?

A. No, I have not.

Q. I understand that it appears from the report of the Department of Commerce, that that proportion is 84 per cent. You are not prepared to make any statement about that. Are you familiar with that report?

A. Yes, but I don't recall that particular figure.

Q. And you haven't it here?

A. No.

Mr. Wilkerson: We will furnish a copy of that report. That is our recollection of that percentage. Mr. Shenehon says it is 84 per cent. of all the commerce of the lake at the Detroit river; so that in order to get the whole commerce on the lakes you have to divide the tonnage on the Detroit river by 84 per cent., if that is the correct figure.

Q. Where a vessel is loaded so that it runs very close to the bottom, is there any element of difficulty or danger that is not present if the vessel is operated in water where it does not run close to the bottom?

A. Yes, it is harder to propel.

Q. It takes more coal?

A. It takes more coal.

Q. Danger of collision is greater?

Mr. Austrian: That is collision with the bottom?

Mr. Wilkerson: Q. They have a term they call "Taking a sheer" whatever that is.

A. In constricted waters, in narrow waters the danger would be increased.

Q. Just explain that a little more fully.

A. Two vessels passing fairly close together in narrow channels, and both of them near the bottom, the suction would be greater probably than if there were more water.

Q. Did I understand you to say that your experience had extended to designing vessels?

A. Yes.

Q. To what extent have you designed vessels?

A. Before I came here, I prepared the plans for the Vaaterland, Zieland, of the American Line; for a number of vessels of the London & Southwestern Railway; the White Star Line in Detroit and have vised plans for a number of other vessels.

Q. What do you mean by that?

A. That is some draftsman has made the plans, but they have met with my approval.

Q. You spoke of some positions which you had held before you came to this country. Just what were those positions?

A. Before coming to this country?

Q. Yes.

A. I engaged in practical ship building.

Q. With whom?

A. On the Clyde, the firm of A. & J. Inglis.

Q. Did you design vessels there?

A. In the drawing office.

Q. You were in the drawing office?

A. Yes.

Q. How long were you there?

A. From 1890 to 1896.

Q. How many others were associated with you in the work in the office, in the drawing office; how many were there there?

A. Oh about 10 I think, 8 to 10; 10 maybe.

Q. Did you have a head draftsman? What I am trying to get at is just the organization.

A. Yes.

Q. Were you the head draftsman?

A. No, I was not the head.

Q. Who was the head?

A. A man named Blair I think.

Q. With these others, you did the work under his direction?

A. Yes.

Q. Now since you have been here, you have acted as a consulting engineer, and you spoke about the use of this tank you have out here.

A. Yes.

Q. Just what kind of work do you do as consulting engineer, and in connection with that tank?

A. In developing the right shape to make vessels.

Q. That is to say you have submitted to you plans for a vessel, and then you make experiments to—

A. To determine the best shape, best form.

Q. That is to say you want to get as little resistance as possible, is that the idea?

A. Yes.

Q. Do you make a model?

A. Yes.

Q. Draw it through the water?

A. Yes.

Q. And have some apparatus which measures the resistance?

A. Yes, sir.

Q. And you have had plans submitted to you and from those plans you have done that measuring of resistance and made your report on it?

A. Yes.

Q. That has been your work in the main has it?

A. No, not necessarily. I have been in New York, in connection with the municipal ferries there. We have had the whole—

Q. What was your work there?

A. With Colonel Stevens; I was with the consulting engineers.

Q. You were constructing boats?

A. We had to pass upon all the plans and general scheme for those vessels.

Q. You examined the plans for the vessels and gave your opinion?

A. Made suggestions as the plans were being prepared, etc.

Q. This statement of Mr. Livingstone, about which I asked you and which you refer to, is one in which he says as follows: (Continuous paging 348) "I am trying to explain it is based on the present rate of freight, 65 cents a ton at the head of the lake. Out of that freight rate is paid about 20 cents a ton for unloading." That is the statement you had in mind is it?

A. Yes.

Q. I notice that Mr. Livingstone there says 65 cents a ton from the head of the lake. That is from Duluth to Cleveland?

A. Yes.

Q. The figures which you have taken here with reference to these two vessels about which you testified specifically are smaller than 65 cents?

A. That 65 cents is what the vessel is paid.

Q. What the vessel is paid?

A. For carrying that ore.

Q. It is paid 65 cents for carrying that ore, and it costs it less than that to carry it?

A. Naturally.

Q. Mr. Livingstone there speaks of a freight rate of 65 cents. That is the rate that is paid to the carrier?
A. To the carrier.
Q. For the service?
A. For the services, yes.
Q. You have some figures which are considerably lower than that. Your figures are the actual cost of service to the carrier?
A. Yes.
Q. And not the charge which is received by the carrier for the service?
A. No.
Q. I just wanted to have the record show that. Where did you get your figures?
A. From Mr. Coulby's testimony.
Q. I assume you have quoted him accurately?
A. Yes.
Q. If you say it is from his testimony?
A. From his testimony.

Re-direct Examination by Mr. Adcock.

Q. Your figures are on the basis of the carrier carrying that amount of freight, that is the cost to the carrier of carrying the same amount of freight, wheat, ore or coal, whatever it may be, in boats with less draft, or less depth of water, the same style of boats as these. That is what your figures are based on, isn't it?
A. Yes.
Q. You didn't calculate any speculative profits, or things like that, in connection with this?
A. No, it is simply the difference due to the difference of draft.
Q. You were connected were you not with the University of Glasgow before you came here?
A. Yes.
Q. And from 1896 to 1900, you were connected with Professor Biles, as consulting engineer?
A. Engineer, yes.
Q. You were in practice with him?
A. Yes.
Mr. Wilkerson: Q. In partnership?

A. No, not actual partnership but I had charge of the designing, in connection with our work there.

Mr. Adcock: Q. That is for that firm?

A. Yes.

Q. Since you have been here, your experience has carried you over a large field of different classes of boats and their design and efficiency, etc.?

A. Yes.

Q. I believe, if I remember correctly you stated that you were the Consulting Naval Architect in connection with the design and building of the steamers Shenango and Cole, being the two large classes of freighters on the Great Lakes?

A. That is not quite correct. I was called in to develop their particular forms, and incidentally, of course, took into account the general structural arrangements and everything else.

Q. But you passed upon the design and form of boat?

A. More particularly the form of the boat.

Q. The form of the boat?

A. Yes.

Q. That is the dimensions, length over-all and beam and depth?

A. And shape.

Q. And shape. Referring to Mr. Coulby's testimony, record page 715, you find the statement that: "The Cole is the largest; she is 605 feet long." Do you not?

A. Yes.

Q. And that is one of the boats that you have just mentioned, whose plans you supervised?

A. Well, my work, as I say, was more in connection with the development of the form of those particular boats.

Q. But that was one of the boats?

A. Yes, that was one of the boats.

Q. And the Shenango, whose experience in carrying freight, etc., on the lakes you have mentioned heretofore in your testimony?

A. Yes.

Q. Now in the investigations which you have made, did you consider the cost of carrying ore in the 440 foot class of boats, as compared with the cost in the two larger classes, the 550 and the 600 foot class? Didn't you find it to be about the same?

A. No.

Q. Referring to the last table there (indicating)?

A. No; it was only on Coulby's figures.

Q. And he only took two boats?

A. Yes, he didn't give any for the smaller ones.

Q. They are building boats now of the different classes, are they not?

A. Yes.

Q. I believe you stated that last year there were 20 new boats of the 440 foot class put in service?

A. Yes.

Q. At the present time isn't it a fact that the boats that are ordinarily carrying ore are out of service and seeking cargoes of different kinds, different from ore?

A. At the present time?

Q. Yes.

A. I understand so.

Mr. Wilkerson: That is they are probably seeking cargoes when business is dull?

Mr. Adcock: They have not got the ore to carry.

The Witness: The ore supply is short just now.

Mr. Wilkerson: Q. The ore supply is short?

A. Yes.

Mr. Austrian: There is just as much ore as there ever was; it is not as profitable.

Mr. Austrian: Q. Professor Sadler, you took into consideration, and only took into consideration in giving the increased cost by diminishing the draft of the vessels the items concerning which you testified on your direct examination?

A. Yes.

Q. You did not endeavor to speculate how that cost might be increased or diminished by things that might happen in the future, did you?

A. No.

Q. If the demand for the raw product, the ore, on Lake Erie and other lakes south of Lake Superior should diminish, naturally the demand for deep draft vessels would probably diminish in the same proportion, would it not?

A. Yes.

Mr. Wilkerson: That is not only for ore, but all other products, you mean?

Mr. Austrian: I will supplement that. Q. The type of vessels concerning which you have testified as the 600 foot and over class are vessels which are known as ore carrying vessels are they not?

A. Ore and coal.

Q. And coal. The coal is carried from the south to the north, and not from the north to the south, isn't it?

A. Yes.

Q. But primarily the vessels are constructed for the purpose of carrying ore from the north to the south on the Great Lakes, the large type of vessels?

A. Yes.

Q. And if the demand for the raw product of ore should be diminished from the ore fields of the north to the smelters of the south on the Great Lakes, in your opinion would that diminish the demand for this large class, the large type of vessels known as ore vessels?

A. Yes, I imagine it would.

Q. If it should appear that the steel industry, located for instance at Gary and at other points on the Great Lakes south of Lake Superior should be moved into Canada, so that the raw product would be diverted from those sections of the Great Lakes at which it is now consumed to Canada, wouldn't that diminish in part the demand for the large type or class of ore vessels of the deep draft concerning which you have testified, in your opinion?

A. Which part of Canada?

Q. Canada to the east of Lake Superior; not south but to the east of Lake Superior above the Soo.

A. Yes, it probably would.

Q. Mr. Wilkerson drew your attention to the fact that a number of vessels are operated after what is known technically as the season of navigation has closed. That fact alone did not create the impression in your mind that there was a shortage of bottomry to carry ore and coal and other kindred products, did it?

A. No, I can't say as it did.

Q. Don't you know as a matter of fact that these large steel industries that cause this ore to be shipped, or who directly ship it, ship only through and by their own vessels, or vessels owned by their constituent companies? Isn't that your understanding of it?

Mr. Wilkerson: Do you know anything about that?

Mr. Austrian: You took him in the line of speculation. I thought I would like to travel in the same field.

Mr. Wilkerson: No, this is hardly speculation.

A. I can't answer that question.

Mr. Austrian: Q. You don't know then?

A. I don't know definitely.

Q. Professor Sadler, do you know of any reason why ore cannot be shipped by vessels or on vessels of the smaller type as well as upon vessels of the larger type, that is the 440 foot type?

A. It can be shipped and is shipped that way.

Q. You know in the Detroit river as well as other points in the Great Lakes, to-wit at Chicago, vessels are operated for the purpose of carrying package freight long after the season of navigation closes, and after insurance is terminated by the various naval insurance companies, isn't that a fact?

A. Yes.

Q. If a vessel is a smaller type of vessel, and it runs north empty, or light as it is called, the cost of operation is less than if it were a larger vessel and went north light. Is that correct? The smaller the vessel if it runs north light, the smaller the cost of operation, isn't it, other things being equal, the same type and same general structure?

A. Yes, a small vessel, yes.

Q. A 400 foot vessel can be taken up north light much cheaper than a 600 foot vessel can be taken up north light, other things being equal?

A. Yes.

Q. Mr. Wilkerson drew your attention to the fact that it was contemplated to increase the depth at the Soo to 24 feet. I believe that was the measurement you used.

Mr. Wilkerson: I think that is the correct figure.

Mr. Austrian: Q. You stated that was your understanding?

A. Yes.

Q. Mr. Wilkerson then went along and said if that was deepened to 24 feet as against 20 feet, 21 feet as it is now, or 19 feet, that would have a tendency to cause vessels to be built to a greater depth and of greater carrying capacity?

A. Yes.

Q. If they should make it 44 feet deep instead of 24 feet deep, that is no reason why you could float the Imperator or the Mauretania through those locks, and do business in carrying freight to the navigable points on the Great Lakes?

A. No.

Q. You would have to adjust all the critical points, the wharfage and bays and means of transportation and handling of these vessels throughout the Great Lakes?

A. Yes.

Q. And widen the channels; and the same holds true, if

we have a deep waterway; the same premises hold true do they not?

A. It would have to be made to suit those vessels.

Q. You would have to readjust the intakes, the bays, the wharfs and everything else to accommodate that draft of boat?

A. Yes.

Q. In other words the mere fact that they should deepen the Soo to 21 feet would not permit you necessarily to increase the draft of vessels, in the same ratio or the same proportion?

A. No.

Q. About the use of these small vessels and the large vessels, it is a fact is it not that since the large vessels came into use freight rates have decreased?

A. Yes.

Q. There isn't any doubt but what the effect of the use of the larger vessels is to result in cheaper transportation and lower freight rates; that is a well recognized principle isn't it?

A. Yes.

Q. Now let me direct your attention to page 9 of this Statistical Report of Lake Commerce passing through the canals at the Soo 1912, the table there at the bottom showing the total freight from the year 1888 to the year 1912?

A. Yes, I have a copy here.

Q. That shows a gradual increase in tonnage right along doesn't it, with the exception of two or three years where business conditions were such that they might be called "off years"?

A. Yes.

Q. The years of the panic 1903 and 1904. I wish you would do a little figuring for me, in view of the questions Mr. Austrian has just put to you.

Suppose during the next 24 years, the business of the lakes should increase the same ratio it has increased during the last 24 years, what would be your capitalized estimate of the damage to navigation 24 years from now, the way you figured it this morning assuming that it increased at the same rate it has the last 24 years. I want you to assume that business on the lakes is going to increase at the same rate during the next 24 years that it has during the past 24 years, and on that basis, with that amount of commerce, I want you to give us

your figures for the damage done by the loss of three inches draft.

A. It would be about $30,000,000.

Re-direct Examination by Mr. Austrian.

Q. Professor Sadler, Mr. Wilkerson has drawn your attention to the fact that the records disclosed that the freight rates have diminished in the last ten years, I think you said?

Mr. Wilkerson: I assumed that to be true.

Mr. Austrian: Q. Since the large boats came in. Does that tend to demonstrate to a certainty in your mind that there is no shortage of bottomry to carry all of the freight necessary to be carried? Under the law of supply and demand, there would be a natural reduction, would there not?

A. That is if there was no shortage.

Q. No shortage? The freight rates have decreased because there has been an enlargement of the carrying capacity. Wouldn't you draw that deduction?

A. Yes.

Q. And so commerce has been accommodated by the amount of carrying capacity that has been put on the fresh water to the extent that there has been no shortage, and therefore a surplus, and therefore the lakes have been diminished or decreased. Isn't that correct in your opinion?

A. That is one of the causes.

Q. One of the causes. Now you have just given a figure of $30,000,000 as a mental calculation of a speculative loss in the next 24 years. That depends on a great many elements doesn't it?

A. Certainly.

Q. For instance, I do not know whether you are acquainted with the ore conditions in the northern part of the lake region; are you acquainted with them?

A. Somewhat.

Q. You know that experts have calculated that the ore fields of the Lake Superior region will be nearly exhausted in from 25 to 40 years; have you ever heard such calculation made; that is at the present rate of consumption of the raw product?

A. I do not recall having seen those actual figures.

Q. If that is a fact, that would be an element to be taken

into consideration in computing this future loss, would it not?

A. Certainly.

Mr. Wilkerson: That is if there was nothing else to take its place.

Mr. Austrian: We will come to that.

Q. Do you know as a matter of fact the timber fields—and lumber is a large item in this freight carryng computation you have referred to—will be inside of the next ten years practically exhausted? If my statement is correct, that will be another element to take into consideration?

A. Yes, certainly.

Q. Of course as the mining of ore and the removal of timber is diminished in the north, the demand for coal to be shipped, for the purpose of mining the ore and moving the timber will likewise be diminished?

A. Yes.

Q. And that will be another element to be taken into consideration. There are a great many elements that are more or less speculative that you would want to take into consideration?

A. Yes.

Q. Before arriving at any figure of $30,000,000 of loss by reason of the lessening of the draft of vessels, 1, 2, 3, 4 or 5 inches in the next 24 years. Isn't that correct?

A. Yes.

Q. You don't want to have it understood that is your computation, that will be the loss by the lessening the draft 1, 2, 3, 4, 5 or 6 inches in the next 24 years?

A. Only if the figure is the same as it has been during the last—

Q. That is the increase in the carrying capacity?

A. Yes.

Q. And the conditions upon which you based your original answer remain the same?

A. Remain the same.

Q. As included in your original answer?

A. Yes.

Q. Another question Professor: Rail shipments are considered much more advantageous than boat shipments, other things being equal, that is cost, cartage being equal, because the transportation is in nine cases out of ten more speedy; the delivery is better and the terminals are better and the terminal facilities are better?

You understand that to be a fact do you not?

A. I don't know; I am not much in the transportation business.

Q. You don't know anything about it, but your general knowledge has taught you hasn't it, that rail transportation is to be preferred to lake transportation or water transportation, other things being equal?

A. Provided the rate is the same.

Q. Other things being equal, cost of cartage and so forth being equal. If within the next 24 years it should become cheaper to ship by rail, or equally cheap to ship by rail as by water these various high priced commodities such as ore, coal and so forth, that would be an element to be taken into consideration in ascertaining these capitalized losses, by the diminishing of 4 or 5 or 6 inches of draft of vessels?

A. Yes.

Adjourned to Thursday, July 17, 1913, the Plaza, New York City, New York.

Thursday, July 24, 1913, 10:00 A. M.

JOSEPH RIPLEY, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name, Mr. Ripley?

A. Joseph Ripley.

Q. Where do you reside?

A. Albany, New York.

Q. What is your business and place of business?

A. Civil engineer, place of business is Albany.

Q. Are you connected now with any public works?

A. Consulting engineer to the State Engineer on the Barge Canal construction.

Q. Did you receive an academic training, a course in any college?

A. Yes, sir.

Q. State where?

A. I took the full civil engineering course University of Michigan, graduated in 1876.

Q. In the engineering department?

A. At that time the engineering department was part of

the literary department. I received the degree of civil engineer at that time.

Q. Are you a member of any society of civil engineers, or societies of civil engineers?

A. Yes, sir, the American Society of Civil Engineers; the Western Society, and several other engineering societies.

Q. Have you been connected with any public work since you received your degree?

A. Yes, sir.

Q. Will you state what boards, or work you have been connected with?

A. In 1877 I was employed on the canal work at Sault Ste. Marie, Michigan, particularly the Weitzel Lock constructed by the Government. Alfred Noble was the civilian engineer in charge.

Q. How long were you connected with that work?

A. I was connected with that work until midsummer of 1906.

Q. Will you state what your duties were, and what particular work you had in charge while you were in the Government service at Sault Ste. Marie?

A. For the first two years I was on the masonry construction of the Weitzel Lock, and then I was on the river work, which included a survey of the St. Mary's river in 1879; and then on dredging and other operations for deepening the channels of that river, and that work extended over a period, while I was there, to 1906. I was in charge of the river work from 1882 on, as assistant engineer, and then in 1897 I became general superintendent.

Q. What was your title Mr. Ripley?

A. At that time?

Q. Yes.

A. In 1898 my title was general superintendent. The general superintendent had charge, local charge of all the river and canal improvements, and the operation and care of the canal.

Q. When you say river and canal improvements, what did that cover geographically?

A. It covered the St. Mary's river from the Iroquois Point, mouth of Lake Superior to Detour, the head of Lake Huron.

Q. Before you became general superintendent, what position did you hold in that service?

A. I was assistant United States engineer.

Q. Now during this period from 1876 to 1906, what par-

ticular river or canal improvements were initiated and completed, with which you were connected and had charge?

A. The masonry work of the Weitzel Lock was started in 1876, and the work of building that lock and completing it was done during that period. The canal was deepened and widened, first, from a depth of 12 feet, a general width of about 100 feet, to a depth of 16 feet and varying widths up to 100 and 200 feet. And then finally to a depth of 25 or 26 feet and widths of 100 to 500 feet.

Q. Was the Poe Lock constructed during that period?

A. Yes, sir.

Q. And put in operation?

A. Yes, sir.

Q. The various channels of the St. Mary's river, the Hay Lake channel, the Neebish channels, Little and West Neebish and the Middle Neebish, were they deepened and widened?

A. Yes, sir, the improvement of St. Mary's river was begun in 1853 by the building of the old State canal at the Soo; and that canal had two tandem locks each 350 feet long, 80 feet wide, with a depth of 12 feet on the sills.

The canal was opened for navigation in July, 1855, and boats drawing 8 feet of water were able to pass through the St. Mary's river. The deepening of the river above the canal and one or two shoals and the dredging and making a new channel in Lake George and the East Neebish, and in the vicinity of the Sailors' Encampment was done in the years 1856 to 1859. During the period from 1859 to 1870, there were some boulders removed from the channel of the river.

With the completion of the Weitzel lock in 1881, the river channels were deepened and widened to correspond to that improvement, and the channel by the way of Lake George was made in general 300 feet wide and 17 feet deep from below the locks to the flats in Lake George.

The channel through Lake George was made 250 feet wide and 17 feet deep and the channel at the East Neebish was made on the American side. The channel which had been used up to 1883 was on the Canadian side of the river at the East Neebish. The channel was 150 feet wide and 17 feet deep on the American side of the East Neebish.

Then the channel was improved through Little Mud Lake and on the limestone rock at Sailors' Encampment. Excavation was made for a channel on the Canadian side of the river 300 feet wide and 17 feet deep.

In 1884 the improvement of the Hay Lake channel by the way

of the Little Rapids and Middle Neebish was started; and that channel was finally completed for a least width of 300 feet, and 20 feet deep with reference to certain grade plane; and opened to navigation in 1894.

The channel through Little Mud Lake was excavated to a depth of 20 feet and a width of 300 feet; widening at the angles, between the years 1892 and 1894. And a new channel on the American side at Sailors' Encampment was made through the Limestone Shoal at that place, for a width of 300 feet and a depth of 21 feet; and opened to navigation in July, 1897.

Under the project known as the 1903 project, the channel through Hay Lake was improved by widening at Little Rapids to 600 feet and deepening to 21 feet, with the grade planes lowered from 4 feet at the locks and 2.7 feet in Mud Lake.

The channel was excavated through the West Neebish Rapids for a width of 300 feet and a depth of 21 feet, deepening to 22 feet in the rock section.

In 1908 to 1912, the middle Neebish route was deepened to 22 feet in the rock sections and 21 feet in the earth sections, with reference to the grade plane described for the West Neebish. Above the locks the channels had been deepened through three principal shoals securing a least width of 1,000 feet, and a depth of 21 feet.

Q. You were engaged in and about this construction work that you have described, the deepening of the channels and the improvement of navigation there?

A. Yes, sir.

Q. You have described the construction work in the St. Mary's river and so forth, under what you call the 1903 project, have you not?

A. Yes.

Q. And that was completed along in 1907, was it not?

A. The West Neebish route was completed in 1907. The deepening of the Middle Neebish was completed in either 1911 or 1912.

Q. You have been engaged in the character of work which you have described there since about 1876, until the present time as I understand it?

A. Yes, sir.

Q. You were familiar with the cost of doing that character of work?

A. Yes, sir.

Q. You are also familiar with the present cost of doing

that character of work, in the construction of channels and so forth, as you have mentioned?

A. I am.

Q. Are you familiar with the various channels and routes of travel for boats on the Great Lakes, and navigation generally?

A. I am.

Q. Will you state what experience you have had in that, and your familiarity with navigation on the Great Lakes?

A. In connection with the improving of the St. Mary's river, I made a careful study of the requirements of the boats for navigating that river, and observed them in running channels and maneuvering in the river under all conditions, and have handled tugs and small steamers and have piloted large steamers through the river and also through Lake Huron.

Q. Are you familiar with the construction work that was done in the St. Clair river, Lake St. Clair, Detroit river and the various harbors of the Great Lakes?

A. The improvement of the Detroit river, I kept posted as to that work while it was in progress, and especially after my assistant, C. Y. Dixon, was assigned to that work, along about 1896, I think it was.

Q. What familiarity have you with the determining of lake levels and the operation of the gages showing the elevation of the lake at various points?

A. Why, I kept posted with reference to lake levels, and especially with reference to Lake Superior and Lake Huron and St. Mary's river, and established of course numerous gages along the river and had observations taken with reference to the fluctuations of the water surface; and then also checked up the bench marks and the zero of the gages at the head and foot of the canal, quite a number—well numerous times.

Q. During these entire 36 years that you have mentioned, since you have been familiar with and actively engaged in work having to do with the navigation of the Great Lakes, have you made a study of the subjects concerning which you have testified, and the lake levels, and the method of determining the stages of the lake by the United States Government?

A. I have given considerable study and consideration to those subjects.

Mr. Austrian: Q. During that course of years?

A. Yes, sir.

Mr. Adcock: Q. In the construction of the Panama Canal, did you have anything to do with that?

A. Yes, sir.

Q. Will you state what positions you have held and what work you have done in connection with that project?

A. I was appointed a member of the Board of Consulting Engineers, in August, 1905; and that board studied and reported as to the type of canal to be built at Panama.

Q. By whom were you appointed?

A. By President Roosevelt.

Q. That was in 1905?

A. Yes, sir. And that board was in session from the 1st of September, 1905, to early in February, 1906.

Q. Who composed the board?

A. General George Davis was chairman; Alfred Noble, William Bartley Parsons, William H. Burr, General Abbott, Frederic P. Stearns, Isham Randolph and myself, were the American members of the board.

There was William Henry Hunter, and Messrs. Geurard, Quellenec, Tincauser and Welcher, representing England, France, Germany and the Netherlands.

Q. How many American members were there?

A. Eight, and five foreign.

Q. What was the purpose of the Board of Consulting Engineers you have described?

A. To recommend the type of canal to be built at Panama.

Q. What recommendations were made?

A. There was a majority and a minority report submitted. The majority report, which was made by the five foreign engineers and three American engineers was in favor of a sea level canal, and the minority report made by five of the American engineers recommended a lock canal with summit level at 85 feet above the ocean.

Q. Were you with the majority or the minority?

A. I was of the minority.

Mr. Wilkerson: Who were the other four?

A. Alfred Noble, Frederic P. Stearns, Isham Randolph and General Abbott.

Mr. Adcock: Q. Is that the type of canal that has been constructed or is being constructed?

A. The type of canal being built is the one recommended by the minority members.

Mr. Wilkerson: Q. That was a majority of the American membership?

A. Yes.

Mr. Adcock: Q. Were you at any time principal assistant engineer in charge of preparation of plans for construction of the locks and regulating works in connection with the Panama Canal?

A. Yes, sir; after Congress approved of the lock type of canal, I was appointed principal assistant engineer, and my duties were the designing and constructing of the locks, dams and regulating works of the Panama Canal.

Q. You had charge of that work, as I understand it?

A. Yes, sir; I assumed the duties of that position on August 1, 1906, and proceeded to organize a force of expert designing engineers and a force of draftsmen to prepare the plans for the locks, dams and regulating works of the Panama Canal; and with that force of about six designing engineers and four draftsmen I had the plans for the locks and dams prepared in less than a year's time.

Q. The plans that you prepared as you have mentioned, are they the plans that have been followed in the construction of the locks, dams and regulating works?

A. So far as the dams and regulating works are concerned, they are practically the same; of course with modification of details in some particulars.

Q. Which arises as the work progresses?

A. But as far as the locks are concerned, we made our studies for locks 100 feet wide and after I had resigned, the change was made to a width of 110 feet. But the general design of the locks and the gates and so on followed what we had prepared, only changed to suit the wider locks.

Mr. Austrian: Q. When did you resign that position?

A. After having served as principal assistant engineer for about six months I was appointed assistant chief engineer, and that became effective I believe the 1st of February, 1907, and I resigned in July, 1907.

Mr. Adcock: Were you connected in any other capacity with the construction of the Panama Canal?

A. Yes, sir; I made a careful study in January, 1907, and April, 1907, of the entire workings of the canal. the construction work and the different departments of organization there relating to commissary, schools, courts, police regulation, but particularly with reference to the construction work along the Culebra divide; the chief engineer, John F. Stevens, having decided to resign; and had notified me that he would recommend me as his successor, which he did when he resigned in April, 1907.

I was also appointed by Mr. Stevens a member of the

Commission of which he was chairman, with the authority to appoint two assistants to represent the Government, and the contractor was to appoint two engineers to represent his side, at the time that the Government was considering the bids received for letting the Panama Canal work by contract. That commission was to determine the cost of the entire work, determine the quantities and fix the unit prices, and the contract was to be awarded at that cost price which we determined upon, plus a commission, a bid commission, a percentage of the total cost.

Mr. Austrian: Q. Plus a bid commission?

A. A bid commission. That is the bid was, as I remember it, about six per cent.

Q. Of the cost?

A. Of the cost.

Mr. Adcock: Q. After 1907, when you resigned as assistant chief engineer of the department of construction and engineering of the Panama Canal, what did you do?

A. I accepted a position of advisory engineer to the state superintendent of Public Works of New York State.

Q. And have you occupied that position since that time?

A. I have occupied that position for about 2½ years. That had to do with the new barge canal construction, the maintenance of the other canals of the state, and new construction in the way of river and harbor improvements, bridges crossing the canals or streams under state control, and building of light houses and so on, of that character.

And then I was appointed a member of the advisory board of consulting engineers, for the state canals, and served in that position about a year and three-quarters when the board was abolished; and then I was appointed consulting engineer to the state engineer for the barge canal construction of New York State.

Q. And that is the position which you now hold?

A. And that is the position which I now hold.

Q. Did you have anything to do with the improvements of the Warrior river, Alabama? If you did, state what connection you had with that improvement, and your duties; the position you held?

A. In August, 1897, I was detailed to make a survey, and plans and estimates for a canal connecting Birmingham, Alabama, with the Black Warrior river.

Q. When you said "detailed," you meant detailed by the United States Government?

A. By the United States Chief of Engineers.

Q. Chief of Engineers, U. S. A.?

A. Yes. I organized a party and made the survey, which covered a distance of 63 miles, and had the plans and estimates prepared, and submitted a report on that project. The work occupied a period of six months. In connection with that work, I had a line of precise levels run connecting Birmingham with the line of precise levels which had been run from Beloxi up to Jackson, Mississippi. The length of that line was something over 200 miles.

Q. Did you lay out the plans for the improvement?

A. Yes, sir.

Q. And had charge of the work?

A. I had charge of all that work.

Q. In connection with the various improvements which you have mentioned in the St. Mary's river and the Panama Canal, have you had anything to do with the determination of the cost of making such improvement, or did you have?

A. Yes, sir; in connection with the river improvement and the canal improvement, where work was to be let by contract I made the estimates of cost.

Q. Mr. Ripley, I understand that you were in the Government service for the year indicated, and that while in the Government service a large part of your time, or some considerable portion of your time, was occupied in making estimates for the United States Government on improvements contemplated, and actually carried out?

A. Yes, sir.

Q. And those estimates that you made followed the usual channels, and were the basis upon which the Government acted in the contemplated improvements?

A. Yes, sir.

Mr. Wilkerson: And I assume are matters of record, aren't they?

Mr. Adcock: Q. And whenever proper they become matters of record?

A. Yes, sir.

Q. Under the usual practices adopted by the Government with reference to estimates. Mr. Ripley, ever since you started in the pursuit of the profession of civil engineering, which I understood you to say was in 1877?

A. 1876.

Q. 1876, what proportion of the entire experience that you have had in that profession has been devoted to the service of the United States Government, just approximately?

A. Why, I was in the service of the United States Government from June, 1877, to July, 1907.

Q. Some 30 or 31 years?

A. Yes, sir.

Q. And since that time, you have been acting in an advisory capacity to the State of New York?

A. The State of New York.

Q. And in that experience that you had, and in the pursuit of the duties concerning which you have testified, a considerable part of that work was done under your direct supervision, and a great portion or some portion of it was by force account instead of contract letting. Is that correct?

A. Yes, sir; and even where the work was by contract, a force account was also kept.

Q. Will you state what you mean by the expression "force account," or what is generally accepted and understood by the expression force account?

A. It is an account kept of the actual force employed and the money spent in wages for employes, and in the purchase of material; and cost of repair work and equipment, so that the entire cost of the work to the Government, or to the contractor, is put down.

Q. And supervised and carefully audited and so forth, and determined?

A. And determined?

Q. Mr. Ripley you stated, at least I so understood you to state, that you devoted a great many years to operations and work in the St. Mary's river, and in and about the locks of the St. Mary's river, is that correct?

A. Yes, sir.

Q. That covered a number of years, did it not?

A. Practically 30 years, with the exception of six months in Alabama and five months on the International Board, and then a year on the Panama Canal work.

Q. The operations which you conducted, and observations which you made and supervisions which you pursued in your work and employment in and about the St. Mary's river brought you in close touch with the conditions existing on the entire basin of the Great Lakes and tributaries, did it not?

A. To a certain extent; yes, sir.

Q. And by reason of that, and by reason of other experiences, you became familiar with the conditions existing in that basin of the Great Lakes?

A. Yes, sir.

Q. Both with reference to navigation, commerce, construction and water conditions I mean?

A. That is it.

Q. And in further connection with your duties in that respect, in and about these various streams, lakes and tributaries, you became familiar with the harbors and canals and basins of the Great Lakes, so far as they were tributary to and immediately adjacent to Canada, did you not?

A. Why, I, of course, was familiar with the entire work on the St. Mary's river, and visited at different times various harbors of the Great Lakes, and the work on the St. Clair river and the Detroit river, and in Lake St. Clair. And in 1903, I made an inspection, personal inspection of the Canadian Canal along the St. Lawrence river, and the Trent Valley Canal, in Canada.

Q. That was in connection with your duties for the United States Government?

A. That inspection trip was simply one that I made on invitation of the Deputy Minister of Marine, Canada.

Q. But your inspection of the work on the Detroit and St. Clair river, that was made at the suggestion of the engineer in charge?

A. No, that was incidental to my work. Whenever I was down at Detroit, I talked over the work with Mr. Dixon, the work that he was doing on that river, and with Mr. Kent, what he was doing on the St. Clair river and Lake St. Clair.

Q. How long were you connected with Mr. Alfred Noble?

A. I was an assistant to Mr. Noble at Sault St. Marie on the canal and river work for six years.

Q. During what period?

A. From June, 1877, to July 1883, I think; 1882 or 1883. And then again was associated with him on the International Board of Consulting Engineers for the Panama Canal.

Q. What was Mr. Noble's position at the Soo?

A. He was general superintendent, in local charge of the canal and river improvements, and the operation of the canal.

Q. That is the Mr. Noble, I believe, that has testified in this case?

A. Yes, sir.

Q. Alfred Noble? Were you connected with Mr. Eben S. Wheeler?

A. Yes, sir.

Q. Who testified for the complainant in this case?

A. He succeeded Mr. Noble as general superintendent at

the Sault Ste. Marie, and filled that position from the time of Mr. Noble's resignation until December, 1897.

Q. When did Mr. Noble resign, about 1883?

A. I think it was in 1882, July, 1882.

Q. And when Mr. Wheeler resigned, you then became general superintendent?

A. I became general superintendent in March, 1898.

Q. And you were assistant superintendent from—

A. I was assistant engineer.

Q. Assistant engineer during the period preceding?

A. During all the time I was there at the Soo, practically.

Q. Who were the engineer officers in charge at Detroit of that district, during that period you have mentioned from 1877 to 1906?

A. General Godfrey Weitzel was the engineer officer in charge of the district, at the time I went to the Soo, which was in 1876, until 1882. He was succeeded by Major F. W. Farquardt, and he was succeeded by General Owen Poe. Major Farquardt was in charge there from 1883 I think to 1885; and then General Poe was in charge from 1885 to the time of his death in 1894, or 1895. And then he was succeeded by Colonel G. J. Lydecker, who had charge until about 1900 or 1901, and he was succeeded by Major W. H. Bixby, present Chief of Engineers, and he was succeeded by Colonel Davis, Colonel Charles E. L. B. Davis.

Q. That was about in 1904, was it?

A. Yes, about 1903; and he was in charge when I resigned in 1906.

Q. Where is the office of the engineer officer, in charge of that district?

A. In Detroit, Michigan.

Q. What does the district cover?

A. The river and harbor improvements, from the mouth of the Detroit river up to Sault Ste. Marie in Michigan, along the Detroit river, Lake St. Clair, St. Clair river and Lake Huron, and possibly the Lake Michigan ports now; and St. Mary's river, up to Lake Superior.

Q. Is that called the Detroit river district?

A. The Detroit district.

Q. While you were engaged at the Soo, what did you have to do with the establishment of gages to determine the elevation of the lakes or lake stages, and the operation of reading and recording the elevation at various times?

A. I checked up the zero of the gage, by running a line of levels from a fixed bench mark at the canal lock.

Q. Where was that gage located, or the gages located that you established?

A. The gage at the head of the canal was located at the outer end of the southwest pier, and the gage below the canal was located near the end of the northeast pier, and the bench mark was on the coping of the old state lock for a while; and then it was transferred to the coping of the Weitzel lock.

We had some bench marks at the movable dam, and then also on the southwest pier.

Q. Did you have to do with any gage located near Lake Huron, to determine the level there at the mouth of the St. Mary's river?

A. There was a gage established at Detour, of a self-recording type, about the year 1904, I think. I am not positive as to the year.

Q. Was there a recording gage established by Mr. Noble in 1877, at the southwest pier, do you remember?

A. There was a gage established by Mr. Noble about the year 1871 at the head of the southwest pier.

Q. What kind of a gage was that?

A. Self-recording gage. But it was of a type that required a great deal of attention, and in the cold winter weather it used to stop running quite frequently. The records of that gage were sent every month to the officer in charge of the district at Detroit, Michigan. That gage was kept in operation until about 1879 or '80.

Q. In connection with your establishment of gages that you have mentioned there, and their operation, did you have any occasion to make a study of the best position to place gages, to determine the elevation of the Great Lakes, or any one of them?

A. The zero of the staff gage at the head of the southwest pier was located in a position that would give the best protection from wave action; but at times, with certain winds, the gage will be exposed to wave action. And the gage located at the head of the northeast pier was on the north side of the pier, and the water was swift and turbulent there, and for a number of years we had the gage in a box, the box open at the bottom, serving as a protection against wave action.

The selection of the best location for the Haskell self-recording gages was given careful consideration. One was established at the head of the southwest pier, and another one on the northeast pier. The floats of those gages are placed in

an iron pipe, the pipe having a small hole near the bottom to allow water to enter, and yet of such a size that the water surface cannot be made turbulent. And then the zero of those gages was checked by staff readings, and of course also by checking up the zero of the gage with reference to a fixed bench mark.

Q. Take for instance a lake like Huron, Michigan, Superior or Erie, I will ask you how many gages you would consider it necessary to place on the lake, and where, not speaking of local conditions, but with reference to the general contour of the lake, to best determine the mean average elevation of the lake?

A. In my judgment, in order to determine the average elevation of the lake, gages should be established near the ends of the central axes. That would require four gages, one at each end of the lake and one at each side opposite the middle of the lake. And I am led to that view, on account of the wind effects and possible tidal action.

At Panama, a line of precise levels was run across the Isthmus connecting gages on the Atlantic side with the gages on the Pacific side of the Isthmus, and recent readings of the water surface on Lake Gatun, between Gatun and Bohio, a distance of 22 miles apart between those gages, with a steady breeze of about 20 miles an hour blowing from Gatun towards Bohio each day, it has been observed that the water surface at Bohio is from 1/10 to 2/10 higher, on account of the wind, and about half that amount lower at Gatun.

Q. You mean 1/10 to 2/10 of a foot?

A. Yes, sir.

Mr. Wilkerson: Are these measurements measurements that you made yourself?

A. No, sir; not on Lake Gatun.

Q. Are they measurements that were made by Government engineers?

A. Yes, sir.

Q. And officially reported?

A. Yes.

Q. Where are the official reports?

A. It is officially reported in the Canal Record, which is a publication made by the Corps of Engineers, in charge of the Panama work.

Q. And for the purpose of your answer, you have taken those reports of the Government engineers, and have given credit to the accuracy of the reports?

A. Yes.

Q. You have assumed that their work has been done accurately?

A. Yes, sir.

Mr. Adcock: Q. Have you reached that conclusion wholly upon the Gatun conditions, or have you taken into consideration your experience in connection with the operation of gages, readings and so forth upon the lakes themselves?

A. I had that opinion long before I saw the reference to the Gatun condition. The results given from the observations there simply confirm my previous opinion.

My opinion has been based upon observations taken along St. Mary's river, and especially on the widened sections that are designated as lakes.

Q. Would the mean elevation derived from the four gages located as you have suggested show a greater or less change of level between its monthly means than would be shown by any one of the gages?

Mr. Wilkerson: I would like to know whether the witness is asked to state a fact which is based upon observations and computations made by himself?

Mr. Adcock: In your opinion, for any lake?

A. In my opinion, the elevation of the lake surface as determined from the mean of the readings of the four gages would be greater or less than the elevation determined from reading the one gage, although at times it would probably be the same.

Q. In other words is it your opinion that the readings of one gage would vary to a certain extent from the true elevation determined by the four gages?

A. I think it would.

Mr. Wilkerson: At the same instant?

Mr. Adcock: At the same period of time for similar conditions?

A. Yes.

Q. At the same period of time. You have stated the location of certain gages at the Soo. Do you know how that location compares with other gages on the Great Lakes, with reference to the ease with which they may be inspected and the observations taken; having in mind the location of the officer, in whose charge they may be?

A. The gages at the Soo have undoubtedly received closer inspection than the gages located elsewhere along the Great Lakes. They may not at the present time be receiving any closer attention than some of our particular gages along the

lakes, but in the past I believe they have received closer attention.

Q. By reason of what fact?

A. By reason of the fact that they were directly looked after by an engineer.

Q. Who was stationed at that point?

A. Who was stationed at the Soo, and had charge of the work there?

Mr. Wilkerson: And from that fact you reach the conclusion that they have been looked after more carefully?

A. Yes, sir.

Q. You are not testifying to any fact based on your own observation?

A. Why, I have had instances related to me by those who claim to know the facts with reference to some of the other gages?

Q. Are you speaking about Lake survey gages?

A. The gages, for instance one at Marquette, in earlier days I have heard—

Q. That is prior to the Lake survey?

A. Yes.

Q. They are all as a matter of fact now under the supervision of the Lake Survey?

A. Yes, I know. Since the Lake Survey has taken care of them, I would not attempt to make any discrimination between the leading gages.

Mr. Adcock: Q. Have you any experience with the inaccuracies of the reading of gages at any point?

A. Yes, sir; at the Soo, the southwest pier is located on a sand foundation, and there is more or less settlement taking place continually, but—

Q. State what the facts were in connection with the piers.

A. The zero of the gage has not always been checked up as frequently as it should have been, and I remember on one occasion that a settlement of about 2/10 of a foot had taken place during the period from a previous checking to the time of that checking of the zero of the gage, by levels.

Q. How long a period?

A. As I remember it, it was a period of nearly two years.

Q. Do you remember the years, Mr. Ripley?

A. I do not, the exact years, but it was around the late eighties or early nineties.

Q. Do you know what kind of gages they had around the lakes, up to say 1903, as to whether they were self-recording?

A. They were mostly what we designate as the staff reading gages.

Q. In other words, a man would have to be there?

A. You have to measure down from the zero of the gage to the water surface, or from the water surface down to the zero of the gage.

Q. Some one would have to be there at a particular time and take the reading?

A. Yes, sir.

Q. And record it?

A. Yes, sir.

Q. Will you state what experience you had in establishing the zero of the recording gage below the locks, and in checking?

A. The staff reading checked from the zero of the gage down to the water surface has not always been made with very great accuracy, with reference to that particular gage. The water is turbulent where the staff reading is taken, and so much so that you cannot tell within possibly three or four inches of where the actual water surface would be, the mean water surface, and a glass tube is used to take the reading; and at the end of that glass tube is a cork, and a hole in that cork and a string passed through the hole, which is knotted on the end, the intention being to pull the knot away from the cork and let the water rise in the tube to what would be the mean height of the water surface outside; but the observer has pulled out the cork and then let the water into the tube, and then pulled the cork up into it, and he might catch it at the high stage or the low stage.

Q. When was this gage established that you have just been describing?

A. In the late nineties.

Q. You have mentioned various improvements in the channels of the St. Mary's river, and the time when the improvements were made. Will you state what the improvements have been in the Detroit river, Lake St. Clair and the St. Clair river, and the depths reached by the particular improvement mentioned, and when the improvement was completed.

Mr. Wilkerson: I do not object to the question, but it occurs to me that with reference to the nature and extent of these improvements, they have all been the subject of such accurate official reports, and the data are so easily obtained, that that is far preferable to the mere recollection of the witness about the facts. I do not undertake to control the di-

rect examination of the witness at all, but I suggest that fact; that these reports will all be in this case as a part of the record, before we are through.

Mr. Adcock: That is true, but he has made an examination of those records, and I think we can get it in.

Mr. Wilkerson: Your idea is, is it not, to take the place of the better evidence on the subject, but it is a summary of the evidence which he has borrowed his conclusion from.

Mr. Adcock: And from his own recollection.

A. For the Detroit river, the first improvement was made at the Lime Kiln Crossing, in the seventies. The channel was made 300 feet wide, finished in 1877; widened to 400 feet in 1886 and 440 feet in 1890, and 600 feet in 1892.

Q. What was the depth prior to the time you have described?

A. The depth from 1877 to 1890 was for 20 feet, with the reference to the datum of 578.01, 1903 elevations, Lake Erie.

Then Bar Point Shoal was made 800 feet wide in 1892, and the Hackett Range 600 feet wide in 1892, and the Amherstburg Beach 500 feet in 1901, and the Livingstone channel 300 feet in 1902, and widened to 450 feet inside the cofferdam in 1911; and the Ballard's Reef, 600 feet 1893, I think, and the depth of those channels to which they were improved between 1890 and 1900, was 21 feet, reference being to reference plane 572.80; and 1900 to 1902, the depth of 21 feet with reference to plane 571.5; 1904 to 1908, 21 feet with reference to plane 571.0. And 1907 to 1912, 22 feet, and 23 feet inside of the cofferdam of the Livingstone channel and 1909 to 1910 21 feet at the Bar Point Shoal; and then that was deepened later on to 22 feet; and from 1910 to 1913 22 feet for the Ballard's Reef. All those since 1904 was with reference to plane 571.0. Those are the clear depths obtained, but payment has been made—

Q. Will you describe how the improvements have been made in the channels and the actual depths of the excavation or dredging.

A. The clear depths secured were those stated, but payment was made at full rate to 23 feet for the work outside of the cofferdam, and inside the cofferdam the full rate has been paid to 24 feet. But they are not required to clean up between those depths. For this 22 feet depth, they are paid full price of 22 feet, and for what they actually take out between 22 and the lower grade, 23 or 24, they are not paid for at full rate.

Q. Why is that done, Mr. Ripley? State your experience and how that custom arose?

A. That was started on my recommendation altogether. In the latter part of 1879, we employed a dredge with a working hour in the deepening of the shoals in St. Mary's river, and another dredge was employed the following years. And we experimented as to the cost of working over a shoal, when the excavation was made close to the required grade, and then for dredging certain depths below that grade, and we varied those depths from half a foot to upwards of three feet. And we found that in sand and clay shoals, it was possible to go at least a foot and a half and preferably two feet or more below the required grade plane for cheapening the cleaning up process, and for the boulder shoals and for rock work to work at least two feet, and preferably upwards of three feet below the required grade plane.

Now, the contractors on the St. Mary's river, where the work was done by the cubic yard, and payment made for bank measurement above a specified grade plane, objected to being paid simply to the grade plane when they were taking out material below that grade plane, and then having the work re-let for deepening in a short period after they had done the work; and of course the bank measurements would be based then on the conditions existing at the time the new work would be let.

Q. As the actual condition of the bottom?

A. Yes, and they were claiming they were taking out material they were not getting any pay for, and so I recommended that a half rate, half the contract price per hour be allowed them for every yard that they removed for a foot below the required grade in soft digging, and in places in the boulder shoals and rock shoals, half price for two feet below.

On the Detroit river, they extended that system somewhat further and they paid full rate prices for two feet below the required grade.

Q. And upon your recommendation that system was followed?

A. Yes, sir.

Q. In connection with the improvements in the St. Mary's river and also in the Detroit?

A. And St. Clair river.

Q. And St. Clair river?

A. Yes, sir.

Q. Is that true also of the improvements, dredging improvements in the harbors?

A. I can't state positively as to that, but I presume it is.

Q. Now, you stated it was found to be better. Will you state why it was so found, after the experiments you had made?

A. It was cheaper for the contractors to work a certain depth according to the character of the material below the required grade plane, and that was fully demonstrated, on a section that we had on the rock work in the Middle Neebish, where the contractor drilled the holes for blasting just to the grade plane, and after removing the blasted rock with the ordinary dipper,—he had a special dipper made with a flat lip, the dipper being about eight feet wide—and he worked over that section eight times, taking only cuts half the width of the dredge, and then had to do a lot of work with a diver in order to clean up to the required grade, because he didn't have more than half an inch up to 4 or 5 inches of water below the required grade.

Q. Now, you have spoken of grade plane, Mr. Ripley?

A. Yes, sir.

Q. And reference plane?

A. Yes.

Q. Will you explain what you mean by those terms?

A. The grade plane is the required elevation of the bottom of the channel. The water surface grade plane would be the grade plane for that stage of water to which the water was referenced to for the improvement.

Q. Do I understand that there is an elevation plane established for an improvement, like for instance the 1903 project, which will run through the St. Clair, Lake St. Clair and Detroit river?

A. Yes, sir.

Q. And the same would be true with reference to the St. Mary's river?

A. Yes, sir.

Q. The improvements in the channels there. Who established that reference plane, in the Government service?

A. The assistant engineer in local charge of the work generally makes the recommendation and it is passed upon by the engineer officer in charge of the district.

Q. Then the grade plane is a certain number of feet below that reference plane, is that it?

A. Yes, it would be a certain number of feet below the water surface plane.

Q. Or the reference plane?

A. Or the reference plane, yes, sir; or the reference plane might be the grade plane, you know.

Recess to 2 P. M.

After recess, 2 o'clock P. M.

JOSEPH RIPLEY, resumed the stand for further direct examination by Mr. Adcock and testified as follows:

Q. You stated in answer to the last question that the grade plane might be the reference plane. Will you state more specifically the distinction, if there is any distinction, or how they might be treated as meaning the same thing. When I say reference plane, I refer to the reference plane of a particular improvement.

A. Yes, sir. The reference plane for channel improvement may be the same as the grade plane, but usually is not. The reference plane for the improvements of the St. Mary's river, for instance, was selected in 1870 by Mr. Noble, and was taken at an elevation which would be below any of the improvement work. That is below the reference plane for any other improvement work?

A. For any improvement work on the river at the canal.

Q. That is prior to that time?

A. No, following the time he selected. And the improvements were made with reference to that plane, and that plane had a certain relation to the mean stage of water, as determined by the gage records up to that time, at the head and foot of the lock. The channel improvements when referenced to that plane also bear a relation to the mean stage of water. Later on, the elevation of that plane with reference to mean tide at New York was determined, and then the sea level was used as a plane of reference.

Q. In other words, for a particular improvement, or any series of improvements that might be carried on, a reference plane was fixed, which was a certain elevation above sea level?

A. Above sea level, yes.

Q. And the reference plane of the improvement was fixed by the engineer officer at Detroit, upon recommendation of the assistant engineer in charge of the improvement?

A. Yes, sir.

Q. Is it your understanding that the reference plane of the particular improvement becomes a matter of record in the department?

A. It does.

Q. Now, when the reference plane was established for an improvement, was the idea in connection with that improvement to obtain a certain depth below that reference plane, or to fix the bottom of the channel at a certain depth below that?

A. Well, the grade plane, or the plane for the bottom of the channel was fixed with reference to the water surface. Of course the water surface being referenced to the reference plane; and as I have already stated, the improvements at the St. Mary's river were started in 1870 with reference to what was the mean stage of water.

Q. Now, is the reference plane fixed at a certain number of feet above sea level for a particular improvement, or is it determined upon?

A. Yes, sir.

Q. Do you know what the reference plane for the 1903 project which you have mentioned for the St. Mary's river improvement was?

A. Prior to 1903, the improvements were referenced to a water surface which was 584.37 above sea level at the foot of the locks, and 581.47 at Mud Lake. The 1903 project, the improvements was referenced to a water surface of 580.37 below the locks and 578.77 in Mud Lake; the variation between those points corresponding to the slope in the river.

Q. That is a supposed water surface?

A. Yes.

Q. Or an actual mean elevation or low water stage?

A. Why, the water stage might get down to that and might not.

Q. But it was an arbitrary plane?

A. Yes.

Q. Fixed at 580.37 above sea level?

A. Yes, for the improvement starting at the foot of the lock.

Q. When you say referenced to water surface, that is a supposed water surface; it is not an actual surface of the water?

A. It is when the water surface is above elevation.

Q. It is merely an elevation arbitrarily fixed?

A. Yes, sir.

Q. Above sea level?

A. Yes, sir.

Q. In making the channel improvements, do they provide

for a certain depth of a certain number of feet below that elevation which you have spoken of?

A. They do.

Q. Is the work done, or was the work done in connection with the improvements, the excavation, the dredging by contract?

A. The work was done by contract.

Q. Under the terms of the contract, may the contractor if he so elects clean up to the depth below, or the number of feet below the reference plane which you have spoken of, or go a certain number of feet below that point as he chooses?

Mr. Wilkerson: I am not going unnecessarily to obstruct the taking of this testimony, but I cannot permit his statement of a conclusion to go in, unless you give the reference in the record to the documents and reports from which these facts may be verified.

Mr. Adcock: We will do that.

Q. What is the custom in that regard?

Mr. Wilkerson: I object to the custom.

Mr. Adcock: Q. Is there a custom?

A. Yes, sir.

Mr. Wilkerson: I object to that.

Mr. Adcock: Q. How long has that custom been in vogue if you know? How long has that practice or custom been in vogue?

A. Ever since I first went on the work.

Q. How years ago?

A. That would be over 36 years ago.

Q. And is it a well recognized and well understood custom?

A. Yes, sir.

Q. With reference to the handling of those improvements?

A. It is.

Mr. Wilkerson: I reserve the right to strike that out on the ground there is no custom established, and on the ground it is a matter that cannot be established by custom. No custom can possibly control in a case of that kind.

Mr. Adcock: Q. Do you know how the reference plane of the 1903 project was fixed with reference to the improvement in the channel of the St. Mary's river?

A. Yes, sir.

Q. Will you state the manner in which that was done?

A. When the project was prepared, the depth of the im-

provement of course had to be stated so it would be incorporated in the Act of Congress authorizing the improvement, and as the prior improvements had been referenced to the mean stage, of water as determined in 1870, and the water at times was below that mean stage, it would not provide navigation for the implied depth of the improvement, and as the department had ruled that for appropriations made along the sea coast the depth should be referenced to low tide, I urged Major Bixby to reference the improvements in St. Mary's river to the lowest stage of water we had, or the probable lowest stage that we would have, and with his approval I prepared the grade plane as stated.

Q. Do you know when you made the recommendations to the engineer officer in charge, Major Bixby, with reference to the fixing of the reference plane of the 1903 project?

A. It was some time during 1902.

Q. Who was Major Bixby at that time?

A. He was the engineer officer, in charge of the Detroit office.

Q. In making the recommendations which you have stated with reference to the fixing of the reference plane of the 1903 project, as stated, did you take into consideration the report of the gagings of the St. Clair river, with reference to the possible lowering of the lake levels by the diversion at Chicago?

Mr. Wilkerson: I object to that as absolutely incompetent in this case for any purpose.

There is the further objection, whether that was taken into consideration or not, if it is competent, is a matter which can be shown only by official records, and not by the frame of mind of the individual. If there are any official records on the subject they should be introduced. If there are no official records, it is absolutely improper for an engineer to say what he had in mind when he did a thing.

A. I gave consideration to the probable lowering of the Lake Huron surface in fixing these grade planes.

Mr. Adcock: Q. As indicated by the reports with reference to the gagings of the St. Clair river made by Mr. Sabin?

A. Yes.

Mr. Wilkerson: I move to strike out of that answer the words "I gave consideration." I submit the witness should tell precisely what he did consider and to what extent he considered it.

Mr. Adcock: I will ask a question incorporating that suggestion of Mr. Wilkerson; that the witness state what he

did particularly consider in connection with fixing the reference plane mentioned.

A. The Chicago canal had been opened at that time, and gagings of the St. Clair river had been made, and some discussion had been had with reference to the amount of the lowering which would be caused by the diversion at the Chicago Drainage Canal.

Mr. Wilkerson: I move to strike out the words "some discussions." I think the witness should state what discussion there was.

The Witness: At that time it was considered that the lowering might amount to as much as eight inches.

Mr. Wilkerson: I submit the words "It was considered" are improper; that he should state by whom, whether by the witness or somebody else.

Mr. Adcock: Q. Mr. Ripley, these considerations which you say prompted you, or which you took into consideration in fixing this reference plane, were those the subject of discussion in the department?

A. I had discussed the matter with Mr. Wheeler at different times.

Q. Who is Mr. Wheeler?

A. E. S. Wheeler, who was formerly general superintendent at the Soo; and also discussed it with my first assistant, who was in charge of the river work at that time, Mr. Benno Rohnert.

Q. Were they recommendations or considerations that were reduced to writing, embodied in a report, either by yourself or your assistants or associates?

A. I discussed the question orally with Major Bixby, and I am under the impression that it was a matter of correspondence as far as a statement in a report to him was made.

Q. At or about that time?

A. At or about that time.

Q. Those discussions, and the fixing of this plane, they were in the course of your official duties at that time?

A. Yes, sir.

Q. And it was work assigned to you, or that came within your jurisdiction?

A. It was work of which I had charge.

Q. And in fixing the plane as indicated by you, you took into consideration all the elements which as an engineer you concluded it was your duty to consider?

A. Yes, sir; I intended that if we had an improvement

for 21 feet that that 21 feet should be available for navigation on all occasions during the navigation season.

Mr. Wilkerson: I submit in this connection—of course this is a subject concerning which the facts have not been called for thus far as I remember—that if this particular matter was the subject of official correspondence, obviously the correspondence is the best evidence; and the testimony of the witness as to what was considered and what was done is improper, and I must therefore reserve the right to strike out the statement of the conclusion of the witness, if it should be found that the matter which he has undertaken to cover is covered by official correspondence.

Mr. Adcock: Q. Mr. Ripley, the grade plane established by you in the manner in which you have just testified was the grade plane adopted in the specifications used in letting the contracts for the various improvements and projects?

Mr. Wilkerson: When you say, in the manner in which he has testified, do you mean taking into consideration the diversion of the water at Chicago, or do you mean simply the figures?

Mr. Adcock: I am just trying to identify the plans.

Q. That is the reference plane adopted in feet?

A. That grade plane was adopted for the improvements between the foot of the lock and the mouth of the river at Detour.

Q. And the specifications for the various improvements on the Hay Lake and Neebish Channel and St. Mary's river—

A. What is known as the Middle Neebish, part of it, those are the specifications.

Q. Issued by the department?

A. Yes, sir.

Q. From the United States Engineer's office in Detroit and based on the grade plane thus established?

A. Yes, sir.

Q. And those specifications of course are official documents?

A. That is an official document.

Q. You say your recommendations to the Engineer officer in charge of the Detroit office were made some time in the year 1902?

A. As I remember it.

Mr. Wilkerson: Q. If I understand it, you recommended a different grade plane from what you would have recom-

mended if there had been no diversion of the water at Chicago?

A. I believe so. I wanted to make sure of having the depth specified in the act available for the shipping interests at all times during the season of navigation.

Q. You thought the diversion of the water at Chicago made it necessary to adopt a different reference plane from what you could have used if there had been no diversion?

A. Yes, sir.

Mr. Adcock: Q. I refer you to plate 18, appearing in Appendix III of the Report of the Chief of Engineers for the year 1900, following page 5400 of that report; the plate being entitled, "Water level of Lake Huron from 1894 to 1900 illustrating effect of withdrawing 10,000 cubic feet per second from Lakes Michigan and Huron," and I will ask you if that is part of the discussion to which you have referred as having taken place with reference to the possible effect of the diversion at Chicago?

A. I don't remember that any reference was made to that plate at that time. There might have been but I don't recall it.

Q. That report was published at the time that you made the recommendations which you speak of?

A. Yes, sir.

Mr. Adcock: It is understood that either side may substitute a copy of the plate 18 referred to, in the record.

Mr. Wilkerson: It is found in the report of the Chief of Engineers for the year 1900.

Mr. Adcock: Q. Under the 1903 project which you have spoken of, were there excavations or dredgings made in the channels of the St. Clair river and Detroit river, at different points?

A. Yes, sir.

Q. Was Lake St. Clair improved at the same time under that project, with reference to navigation?

A. It must have been.

Q. Is that your best recollection?

Mr. Wilkerson: Is this something that he had to do with; did he have to do with the imrpovements in the St. Clair?

The Witness: I had no charge of that work at all, but simply discussed the improvements with the engineers who did have charge of it from time to time, as I happened to meet them.

Mr. Adcock: Q. And you were in that locality every year were you not?

A. Yes, sir.

Q. And saw the improvements as they were going on?

A. I did not pass through Lake St. Clair every year. I was down to Detroit every year, and some years I went down by boat or returned by boat, but not always.

Q. Have you a reference to an improvement made in the Detroit river in 1901, and can you state what the reference plane of that improvement was? When I say Detroit river, I mean the lower Detroit river.

A. The improvement in 1901 was referenced to a datum of 571.5 above sea level, and that improvement was for 21 feet depth.

Q. Now was there an improvement made in the Detroit river in 1904, that is the next improvement?

A. There was an improvement made in 1904 and the depth was for 21 feet. The datum plane was 571.0.

Q. That was the reference plane of that improvement?

A. Yes, sir.

Mr. Wilkerson: Q. Do you recall where the reference is in the report of the Chief of Engineers, so that we can get the full details about that?

A. I made an investigation through the reports of the Chief of Engineers, and have a tabulation of the various improvements there in the Detroit river.

Mr. Wilkerson: Of course as to the work done under the personal direction of the witness, where he knows the thing of his own knowledge, we are entitled to the source of the information and the reference to the official report in which it is found.

Mr. Adcock: Q. There has been considerable said about the mitre sill of the Poe lock at the Soo. Will you state how that is constructed, and when that became the critical point in the navigation of the St. Mary's river?

A. The elevation of the floor of the Poe Lock is 562.37. The mitre sill, the lower mitre sill is located opposite the gate recesses of the lower gate and the intermediate gates. The floor of those recesses is a foot and a half lower than the general floor of the lock. The mitre sill is either 14 or 16 inches in height. Below the mitre sills for the intermediate gates and also for the lower lock gates, are platforms built of 12 by 12 timbers; the platforms being, as I remember it, some 30 feet along the axis of the lock.

Below the lower guard gates, a platform was built which is .33 of a foot, or about 4 inches higher than the floor of the lock. The Poe Lock was opened for navigation in August, 1896, but the depth over the mitre sills was not available to navigation purposes until the spring of 1898 as the sill and platform for the movable dam located across the canal about 3,000 west of the Poe Lock was left in place until that time, and on that guard gate sill, the depth was only 17 feet.

The opening of the West Neebish Channel in 1907 made the Poe Lock the critical place as to the depth of water for navigation purposes in the St. Mary's river.

Q. And that has remained so to the present time?

A. And that has been the case since that time.

Q. Now is it the mitre sill of the Poe Lock, or this platform that you speak of which is 4 inches above?

A. The platform is the critical place, the platform below the guard gates.

Q. Does the platform below the guard gates that you have mentioned serve any purpose in connection with the operation of the lock, or the passage of boats through there?

A. It was put in for the purpose of protecting the lower mitre sill of the lock.

Q. In your opinion, is it necessary for that purpose?

A. It is not, because the platform directly below the sill could be utilized for that purpose, and that would not necessarily be any higher than the general floor of the lock.

Q. And the mitre sill would be protected for all purposes by that?

A. Would be below that.

Q. Have you made any estimate of the cost of removal of that platform below the guard gate that you have mentioned?

A. I have.

Q. Which is four inches above the floor of the lock?

A. I believe that a cofferdam can be built and the platform removed to correspond with the elevation of the floor of the lock for a cost of about $6,000, and certainly for a cost not exceeding $10,000.

Q. And that could be removed in the winter time without any interference with navigation?

A. During the winter season, without interfering with navigation.

Q. Do you know what the depth provided for in the lock that is being constructed there now is?

A. For about 24½ feet with reference to the grade planes established for the 1903 project.

Q. What is that lock called or what is it to be called?

A. The first one I believe is to be called the Davis Lock.

Q. Is there a second lock?

A. There is another one that has been authorized, and that will probably be called the Townsend Lock.

Q. What is the depth for that lock?

A. At the present time there has been no change in the plans for increasing the depth of the Townsend Lock over that of the Davis Lock, although the General Superintendent has given consideration to that and may possibly recommend an increase of a foot or so.

Q. Have you made any estimate of the cost of increasing the depth of water, the available depth of the channels of the St. Mary's river, St. Clair river, the channel in Lake St. Clair and those of the Detroit river to 4 inches or 8 inches, or intermediate inches between those?

A. I have.

Q. State what estimates you have made and your conclusions.

A. I have prepared estimates for increasing the clear depth an additional 4 inches, and also an estimate for increasing the clear depth an additional 8 inches through the channels mentioned, and through the shoal at the foot of Lake Huron.

Q. State what the costs are.

A. The cost for deepening an additional 4 inches through those channels totals $159,538. And for maintenance on account of deepening the channel, which will disturb the streams entering into the rivers and require an annual maintenance for a while brings the total up to $163,990. And the estimate for 8 inches is $403,854.

Q. Would the cost for 5 inches or 6 inches be proportional, practically?

A. Practically so.

Q. And for 3 inches or 2 inches?

A. It would be less than for the proportional amount of either the 4 or the 8.

Q. Have you given consideration to the cost of the improving of the harbors on the Great Lakes?

A. Yes, sir.

Q. Will you give your estimates of the cost for 4 inches and 8 inches?

A. Yes, sir. For 40 harbors on Lake Michigan, 5 on Lake Huron, for the docks along the St. Clair river and along the shores of Lake St. Clair, Detroit river; for 13 harbors on Lake Erie, and for the Niagara river and 7 harbors on Lake Ontario, the estimate for four inches additional deepening is $1,373,207; and the maintenance on account of stream adjustment amounts to $661,626. For the same harbors and docks, the estimate for 8 inches would be, for deepening, $2,746,414, and for maintenance $992,440. And for the harbors in Canadian waters 34 in Lake Huron, the docks along the St. Clair river and Lake St. Clair and Detroit river; the 12 harbors in Lake Erie and 23 in Lake Ontario, the estimate for 4 inches of deepening is $630,709, and for maintenance $62,432. And for the 8 inches deepening, the estimate is $1,261,418 and for maintenance $93,648. Or a total for the channels, United States harbors and Canadian harbors for 4 inches deepening is $2,163,454; maintenance $728,510; and for the 8 inches deepening is $4,405,008; maintenance $1,092,766.

Q. And the cost of the deepening of 4 inches or 5 inches or any intermediate figure between 4 and 8 would be proportional with reference to the harbors, would it?

A. Practically so, yes, sir.

Mr. Wilkerson: Q. By practically you mean it increases some as you get deeper?

A. No, for the harbors, it would be directly proportional; for the channels it would not be exactly proportional.

Mr. Adcock: Q. And as to any lesser depth than 4 inches, would it be proportional?

A. Yes, sir.

Q. Have you given any consideration to the cost in connection with the canals; that is to provide for 4 inches, 6 inches greater depth?

A. For canals?

Q. Yes, for the canals that are in existence?

A. Yes, sir, for the canals which would be affected by a lowering of the surface of the lakes, on account of the diversion at Chicago?

Q. Well, on account of any lowering of the lakes, without reference to any diversion?

A. For a lowering of 4 inches and 8 inches?

Q. Yes, what is the cost?

A. It would be about one and a half million dollars.

Q. For 4 inches or 8 inches?

A. It would not make much difference, and I did not try to make a distinction between the two.

Q. Why wouldn't it make much difference?

A. Yes, I did too; I did make a difference. There would be some difference on the excavation for the lock, at the approaches to the locks, but the actual changes at the locks, there would not be a great deal of difference.

Q. That is, for practical purposes it would be about the same?

A. Yes.

Q. Will you state why, more particularly?

A. The changes which would have to be made at the locks would be the lowering of the mitre walls, mitre sills; the deepening for the greater height of the gates.

Q. You would have to change the gates anyway?

A. Would have to put the bottom of the gate lower by the amount that you were deepening. For that purpose, you would have to excavate across the site of the gate between the gate recesses.

Q. Have you examined the work of the International Waterways Commission with reference to the regulation of Lake Erie, and the discussion of the effect of the diversion at Chicago, in the 1912 progress report?

A. I have.

Q. Have you considered the estimates made there with reference to cost?

A. I have read the statements made with reference to the estimates of cost.

Q. Have you any opinion as to the correctness of the estimates made?

A. I don't think the estimates are correct, based on the method which they used. For instance they state that about $20,000,000—

Mr. Wilkerson: Q Referring now to what page of the report?

A. Page 72 of the 1912 Progress Report.

Q. By whom is the report signed?

A. Signed by the Commission.

Q. The entire Commission?

A. Yes, sir.

Q. Signed by both the Canadian and American members?

A. Yes, sir. (Last answer read as follows: "I do not think the estimates are correct based on the method they used. For instance, they state that about $20,000,000)—of

which ¼ was for maintenance has been expended on 35 harbors on Lakes Michigan, Huron and Erie. The average increase of depth is 10 feet, and the cost per foot of increase was therefore about one and a half million dollars; but as the cost of a small increase would be much greater per foot than an increase of 10 feet, and as several harbors on Lake Ontario are to be added, the cost per foot in this case would probably be not less than $2,000,000 for harbors in the United States.

The expenditure of $15,000,000 on those harbors included piers, break water construction, and for a deepening of 4 or 8 inches, the piers nor the break waters would have to be added to.

The cost also included the high prices paid in earlier days for excavation. For instance, on the Detroit river, as high at $7.50 a yard for rock excavation was paid, whereas the same class of work is being done in the Detroit river at the present time, or has been in the past 2 or 3 years, at a cost of less than $2 a yard for rock excavation. In the same way, the price for earth excavation was much higher at times for that earlier work than the prices now paid for similar excavation.

The estimate also includes an amount of $4,115,430 for deepening the Detroit river 1 foot; and an amount of $1,080,720 for deepening the channel in the St. Clair river, and at the foot of Lake Huron. The estimate also includes three million dollars for the deepening of the Canadian harbors and two and a half million dollars for deepening the approaches, and making the changes in the end locks of the Canadian canals.

Mr. Adcock: Q. There is an estimate there, or some statement, with reference to the depth in Lake St. Clair. What have you to say concerning that statement?

A. Quoting from the report, page 72:

"In Lake St. Clair, the full depth of the lake is now utilized, and any lowering of its surface involves the excavation of an artificial chanel entirely across the lake, a distance of 18 miles, of which it has been necessary heretofore to artificially deepen only one third. To deepen the channel here, and at certain shoal places in the St. Clair river and at the foot of Lake Huron is estimated to cost $1,080,720. It results in replacing open lake navigation by canal navigation for a distance of 12 miles in Lake St. Clair, a decided disadvantage."

Q. What are the facts concerning that?

A. The facts of the case with reference to Lake St. Clair are that under the 20-21 foot ship channel project of 1892 or 1893, the channel across Lake St. Clair was dredged for a width of 800 feet for the entire distance from the foot of the St. Clair Flats Canal to Grosse Point, with the exception of a distance of about 1⅛ miles and that at the present time, on account of the movement of the material from the bed of the lake along the line of the channel, over 2,000,000 yards which have been stirred up by passing boats has been carried off to one side of the channel; and at the present time the channel across Lake St. Clair, with the exception of a short distance below the St. Clair Flats Canal, and for a distance of about 1⅛ miles on the Grosse Point Shore, is from 16 to 1800 feet wide, and from 24 to 25 feet deep.

Q. How has that effect which you mention been accomplished?

A. By the passing boats and the action of the wind and current on the waters of the lake.

Q. In connection with the making of your estimates on cost of the deepening which you mentioned, did you obtain the soundings made by the Government with reference to the depth in the channels which you have mentioned, and also in the harbors, and used those as a basis for making such estimates?

A. The final estimate soundings for the improvements in St. Mary's river below the locks, St. Clair Flats Canal, Lake St. Clair and Detroit river, have been furnished me through Professor Williams; those soundings being the soundings taken by the Government Engineers.

Q. Have you given any consideration to the cost of the construction of compensation and regulating works to raise the levels of the various lakes mentioned?

A. Yes, sir.

Q. That is Huron-Michigan, and Erie and Ontario and St. Clair, and the tributaries or connecting waters?

A. Yes, sir I have.

Q. Will you state where you would place such compensation and regulating works and the cost; and the effect with reference to the raising of the levels of the lakes?

A. The site for which I estimated for the location of a dam on the St. Clair river is situated about 1300 feet upstream on Bunce creek, which is a short ways above Stag Island.

Q. Is that what is called a regulating work? Just state the distinction between compensation works and regulating works.

A. The distinction as made by the International Waterways Commission is that the compensating works are fixed weirs, and the regulating works are a combination of fixed weirs and movable dams.

Q. Is that for the purpose of keeping the levels at a certain range?

A. Keep them within a certain range of fluctuation.

Q. Of what advantage are the regulating works to navigation generally?

A. If the lakes and connecting rivers were regulated within the possible limits of fluctuation, the navigation would be greatly improved.

Q. Would that be in addition to the additional depth of water that they might obtain?

A. Well, it would be additional depth, and the surety of always having that depth.

Q. That is the vessels could load to a certain depth?

A. And navigate different lakes.

Q. And be sure of obtaining that depth?

A. Yes, sir, under the present conditions.

Q. In other words it would be an aid, a convenience to navigation?

A. Yes, sir.

Q. And helpful in the design of vessels too?

A. Yes.

Q. Will you describe the regulating works that you mentioned?

A. A dam could be built at the location I mentioned in the St. Clair river for regulating the levels of Lake Huron and Lake Michigan, and that part of the St. Clair river up-stream of the dam. Another dam located in the Detroit river on the Stony Island Section, and closing the gap between the stone now piled in the river along side the Livingstone Channel to Bois Blanc Island would provide the regulation for the upper Detroit river, and Lake St. Clair and also St. Clair river.

A dam placed in the Niagara river, either near the upper end of the river or down below Tonawanda would provide for the regulation of Lake Erie. But if the dam was located below Tonawanda, it would probably be simply a compensating dam, and not a dam for regulation.

Q. Now those regulating and compensatory works you

have spoken of would not interfere, in your opinion, with navigation, would they?

A. They would be a benefit to navigation. If you put in compensating works, for instance, at the lower part of the Niagara river below Tonawanda, you would raise the mean stage of Lake Erie by the amount you desired within small limits that is within the limits of the lowering which would be caused by the diversion at Chicago.

Q. Have you figured out the cost of those works?

A. I made an estimate of cost.

Q. Will you give them, in the order in which you mentioned them?

A. For the St. Clair river, the estimate, depending on the type of dam to be built, would range from $500,000 to $1,300,000; for the Detroit river, between $40,000 and $150,000; the Niagara river $850,000 to $2,500,000.

Q. From one to the other?

A. Yes, $850,000 the lowest and $2,500,000 the highest.

Q. Depending upon what?

A. Depending upon the type of dam and the extent of the regulating feature. And the St. Lawrence river, from $200,000 to $1,000,000.

Q. Dependent upon the same thing?

A. Yes, sir.

Q. What increase of levels did you contemplate in the estimate?

A. Why by those dams you could provide an increase anywhere from 4 inches to a foot; possibly more than that if it was desirable.

Q. In your opinion as an expert, and based upon your experience, you haven't any doubt that such increase of levels could be made by the compensatory and regulatory works that you have mentioned?

A. I have no doubt as to securing that object.

Q. And if you desired to increase the height of lake levels above the figure that you have mentioned, 4 inches to a foot, would such increase multiply the cost in the same ratio?

A. No, sir, it would add a very small amount to that cost.

Q. How would the regulating works affect the currents in the St. Clair river?

A. With the dam located at the site I have mentioned, the current at Fort Gratiot should be lessened, and that is the place of the swiftest current in the St. Clair river.

Q. And the lessening of that current would improve navigation?

A. Would be a benefit to navigation.

Q. Have you considered the sailing courses of vessels in the freight carrying trade upon the Great Lakes?

A. I have, as chartered on the Lake Survey charts.

Q. There has been some mention of critical areas opposite or off Thunder Bay Island, Sleeping Bear Point, and Poe Reef. What are the conditions of navigation there at the present time?

A. On the course laid out from Pointe Aux Barques, up past Thunder Bay and Thunder Bay Point, there is a shoal in which the depth is about 25 or 26 feet; and of course that would be dangerous to navigate in a heavy storm, but by changing the course so as to clear the point by about 10 miles, a depth of at least 14 fathoms would be secured, and the distance from Pointe Aux Barques to Detour would be increased by about a mile. It would only be necessary to navigate on that course during stormy weather. The inside course could be used in ordinary weather.

Q. And lowering the levels full 5 or 6 inches would not affect the navigation there in calm weather?

A. No.

Q. What has been the custom with reference to following the inner course that you have mentioned, or the shorter course, in stormy weather, prior to 1900?

A. Without the storm comes up when they are sailing along that course in that vicinity, the boats would keep on the outside course. At Poe Reef, the water is only about 4 fathoms deep on the sailing course that is laid down on the charts, but by going to the northward and lengthening the course there about a quarter of a mile, you can get better water, safe navigation.

Q. To what depth?

A. Well, about 6 fathoms.

Q. That is about 36 feet?

A. Yes, sir; and on Sleeping Bear Point, the course passes over a shoal on which there is about 4 fathoms, but by keeping out further and lengthening the sailing distance about 1¼ miles, upwards of 6 fathoms of water can be obtained. At the foot of Lake Huron, the shoal there extends out 5 or 6 miles, but under present conditions it is necessary to deepen that shoal anyway.

Q. I understand you have been familiar right along every

year with the amount of freight carried and the bottoms necessary to carry freight and so forth. Do you know whether in the wheat, coal and ore carrying trades there have been vessels idle each year, or not?

A. While I was at the Soo, I gave particular attention to the navigation part, lake carrying traffic, and without exception every year that I was there, there were some boats idle during part of the year; boats which were classified as freight boats.

Q. It was part of your duties, or in the course of the conduct of your duties and affairs up there, to observe the conditions of freight traffic and the handling of freight through the Soo?

A. Yes, sir.

Q. And did you observe that the carrying capacity was sufficient to meet the requirements of the business?

Mr. Wilkerson: What business?

Mr. Adcock: The freight business.

Mr. Wilkerson: Business to and from the Soo?

Mr. Adcock: The lake traffic.

Mr. Wilkerson: It requires a pretty comprehensive knowledge on the part of a man to know about the ore mines and the wheat fields.

Mr. Adcock: Go ahead.

A. The amount of freight to and from Lake Superior by boat was taken care of each year by the boats. Of course there were some cargoes of grain possibly, or iron ore downbound, and some cargoes of coal upbound, which might have been carried if the navigation season had been a little longer. But under the conditions that prevailed, all the freight that had to be moved, or was desired to be moved could have been moved during each season of navigation, if all the boats had been utilized all the season.

Q. And some seasons would not require the use of all the boats?

A. Possibly not.

Q. Mr. Ripley, I show you a pamphlet purporting upon its face to be a special report of lake commerce passing through the canals at Sault St. Marie, Michigan and Ontario, during the season of 1912?

A. Yes.

Q. Will you just state what that is (handing same to witness).

A. That is a statement of the traffic passing through the Soo canal, the American and the Canadian canals.

Q. For how many years has such a publication been issued?

A. When I was appointed general superintendent there in the spring of 1898, and for two or three years after that, the record of the freight passing through the canal was kept in certain record books, and the publication of the traffic was made by some of the local papers for certain particulars of the traffic. I had the record books changed and some new ones added whereby the records were kept up to date, and then I had the data published in this form, working out the headings for the different tables, and deciding on what tables to insert.

Q. That appears to be issued and prepared under the direction of Lieutenant Colonel Mason M. Patrick, Corps of Engineers United States Army. The ones that were issued during your incumbency up there covered what years?

A. Well, for a year or two after I was there the data was published in newspaper form.

Q. After you started the compilation?

A. No, just in the local papers there. I think this form was gotten up about 1900.

Q. They were published annually in the years indicated by you, under your supervision and direction?

A. The statement is the same as it is here, only giving the name of the engineer officer in charge, and then in the text the statement was made the same as it is here with reference to the general superintendent.

Q. And you were the general superintendent?

A. Yes, sir.

Q. Whose name was mentioned?

A. Yes, sir.

Q. Included in this pamphlet which appears to be issued under the personal supervision and direction of Lieutenant Colonel Mason M. Patrick, impressario, it shows the steamers, the freight, total freight as to valuation, freight charges, average hauling distance freight was carried, freight per ton per mile; shows the carrying capacity of steamers, the largest single cargo, greatest number of mile tons, and everything or practically everything pertaining to the freight carrying business for the year in question, 1912?

A. Yes, sir.

Q. Likewise the character of the freight hauled, coal, lumber and building materials and so forth?

A. Yes.

Q. And it is the most comprehensive document that you know of covering that subject is it not?

A. Yes, sir.

Q. And you inaugurated the style of the pamphlet, and was the first one to collect the data upon which the pamphlet was subsequently published?

A. I originated the form of the pamphlet, but the collection of the data was made from 1881.

Q. After you took charge you revised the method?

A. Yes, sir.

Q. It is by reason of that fact, among other facts concerning which you have testified, that you claim to have familiarity with the freight carrying capacity and so forth as incorporated in the question put to you a few moments ago?

A. Yes, sir.

Q. What percentage of the freight carrying capacity on the Great Lakes passes through the Soo?

A. About 80 per cent.

Q. In your estimates for the cost of deepening the harbors that you have mentioned, did you take into consideration more or less harbors than are mentioned in the report of the International Waterways Commission referred to?

A. More harbors, both United States harbors and Canadian harbors.

Q. They took in something like 35 and you took in 60?

A. I gave the numbers in my answer, and the numbers are stated here in this report as to what the Commission used.

Mr. Adcock: That closes our direct examination, unless we think of some question we have omitted.

Cross-Examination by Mr. Wilkerson.

Q. How long did you say you were engaged in work in connection with the Panama Canal?

A. The work of the International Board of Consulting Engineers extended over a period of a little over five months and then I was employed on the work as principal assistant engineer, or assistant chief engineer for a period of practically one year.

Q. You testified as to the making of certain plans, some

of which I think you said were utilized, and some of which were superseded by other plans. Just which ones of your plans were used and which were not used?

A. The plans for the locks had to be changed on account of widening the locks from 100 feet to 110 feet. That included the lock walls, the culvert construction layout, the gates, and such particulars as those along that line.

Q. Who was in charge of the work on the Panama Canal, while you were there?

A. John F. Stevens, was the chief engineer until April 1, 1907, and on that date Col. George W. Goethals, lieutenant colonel of engineers at that time assumed that position.

Q. Your connection with the work terminated in July?

A. In July.

Q. In the July after the appointment of Colonel Goethals?

A. Yes, sir.

Q. Why were the locks widened there?

A. The officials in the Naval Department were insistent that the locks should be made wide enough so as to give a clearance of at least 12 feet for the passage of their battleships through the locks.

Q. Was it to comply with the growing necessities of commerce, the trend in vessel building being towards the use of larger vessels, is it not?

A. The instructions to the Board of Consulting Engineers was to consider the largest available ships then built, and those probably to be built within a reasonable future time, and we did consider that; and the recommendation by the minority members was for a lock 95 feet wide, by the majority members for a lock 100 feet wide; the majority members recommending a type of lock canal on which to make a comparison with the sea level canal, and then also the sea level canal plan had tidal locks on the Pacific side.

Q. Well, give us the facts about the depths and the other measurement?

A. The depths of the canal?

Q. Yes?

A. The depth recommended by the majority and minority members both was 40 feet sea water or 40½ feet, practically, fresh water. And that was the depth over the mitre sills of the locks and the least depth in any of the channels, any of the channel construction along the line of the canal.

Q. Why were those plans about the size of the locks changed, who did that, who made it 110 feet instead of 100?

A. The change was ordered by the President of the United States on recommendation of the Canal Commission.

Q. When was that done?

A. That was done shortly after I resigned, or about that time.

Q. That is to say they wanted to provide for larger vessels, that was the gist of the matter was it not?

A. They wanted to provide greater clearance than we thought necessary, for the naval boats.

Q. Do you know the history of the growth of vessels in size and draft on the ocean, not for purposes of war alone, but for commercial purposes?

A. In connection with the study that we made for the Panama Canal, we gave consideration to that subject.

Q. And isn't it a fact that the tendency has been towards using vessels of larger size right along, for commercial purposes?

Mr. Adcock: Where, on the ocean?

Mr. Wilkerson: I am speaking of the ocean.

A. The dimensions of ocean boats have been increasing.

Q. Right along?

A. Yes, sir.

Q. That is the general commercial tendency wherever there is navigation, isn't it?

A. Yes, sir.

Q. And any place in the world?

A. (No response.)

Q. You have had a long experience in connection with the lakes, and have been observing them from almost the very beginning of navigation. What has been the tendency on the lakes as to the increase in size of vessels?

A. The tendency has been to materially increase the size of the vessels on the lakes.

Q. Has it not been to build right up to the limits of the critical points of navigation; to make boats just as large as could possibly be used within those limitations?

A. Yes, sir.

Q. And even to crowd those limitations?

A. Generally they have crowded the capacity of the channels.

Q. And whenever in these critical points which place the limit upon the size of the vessel that can be used, there is a change made which makes it possible to build larger vessels, those appear in the commerec on the lakes, do they not?

A. Yes.

Q. Almost immediately, isn't that a fact?

A. The growth has been very rapid, the increase in size of vessels.

Q. What will be the effect when the 24 foot lock is available at the Soo, upon the size of vessels?

Mr. Austrian: That is in your opinion?

Mr. Wilkerson: Certainly.

A. The vessel interests will demand an increased depth in the channels to correspond to that available depth in the lock.

Q. In order that larger boats may be built?

A. Yes, sir.

Q. And the same thing will be true when the 25 and a half foot lock, number 5 is ready for use, in your opinion?

A. Yes, sir.

Q. In connection with the work which you did on the Panama Canal you had something to do with some observations in the reading of water gages; you mentioned that?

A. Why they had a hydrographic department there, in which gages were read, and I have given some consideration to that work.

Q. You stated in your opinion, as I recall your testimony, you would get better results as to the average stage of the lake if you would read 4 gages and combine the observations?

A. Those gages being located near the ends of the central axes of the lake.

Q. You made a study of the results of these readings on the gages on the Panama Canal; that is you saw the reports?

A. I saw the reports in the Canal Record.

Q. Have you made any examination of any of the gages, readings of which have been referred to in the testimony in this case?

A. Excuse me, what gages are you referring to, down there at Panama or up here?

Q. Up here, on the lakes. What I mean is have any of these readings been submitted to you for any critical study in this case.

Mr. Austrian: Is that cross-examination?

Mr. Wilkerson: Yes.

Mr. Adcock: We haven't mentioned any readings.

Mr. Wilkerson: Of course it is cross-examination. He has made some observations here, or insinuations at least, that in some way more or less mysterious these observations which

we have used are not entitled to full credit. I want to know whether he has made any study of them?

Mr. Austrian: We do not object as far as any question put to him. He does not know how you made the gage readings. We just asked him how in his opinion gage readings should be made, that is all. We have not directed his attention towards your gage readings or our gage readings.

A. What is the question?

Mr. Wilkerson: Q. Was your attention called to any of the gage readings in this case, used in evidence in this case? I direct your attention specifically to the gage readings at Cleveland in Lake Erie?

A. I have seen published records of the Cleveland gages and other gages in this matter, but I have not given careful study to the subject of those gages, for the purpose of working out any of the problems in this case.

Q. Prior to the time you formed your opinion as to the method which should be pursued in order to get the most accurate results from gage readings, did you make any comparison of the gage readings at Cleveland and Buffalo for the purpose of seeing how nearly they agreed?

A. I did not.

Q. Nor have you compared the gage readings at Milwaukee and Harbor Beach?

A. I have in years past compared the readings of Milwaukee and Harbor Beach.

Q. How long ago?

A. That was when I was up at the Soo along in the eighties I think.

Q. But not in recent years?

A. Not in connection with this case.

Q. Not any observations for the period from 1890 to 1910?

A. No, sir, I think not; if I have, it has only been casually.

Q. You have presented here certain figures upon the subject, first, of your estimate of what it would cost to deepen the channels and harbors of the lakes, and the rivers connecting them; and you have given us here a general statement of your conclusion as to what the cost would be of making certain deepenings. I will ask you whether you have here available a statement which indicates in detail the work which in your opinion it will be necessary to do to procure a deepening of those harbors and channels to the extent which you have indicated?

A. I have.

Q. That is to say you have a statement in which you have set down the amount of the excavation which you think will have to be made?

A. Not always in terms of excavation.

Q. Or dredging?

A. For the river channels I have based my estimate on the experience obtained in connection with the improvement work of St. Mary's river and with the improvement of the New York State canals, and the soundings shown on the final estimate sheets, or the final estimate soundings as furnished by the engineer department, of those shoals and channels, and I have estimated the number of hours' or days' work for different kinds of plant; for instance the raft with the bars, in order to swing over the channels and determine the location of the points projecting above the proposed deepening; and then for the employment of dredges and of drill boats, and of diving outfits.

Q. You have reached the conclusion, as I understand you, that the figures which are put down in the report of the International Waterways Commission are too high?

A. Yes, sir.

Q. And have you studied the work which, in the opinion of the International Waterways Commission, it is necessary to do to get this deepening, with a view to finding out whether the difference between yourself and the International Waterways Commission grows out of the fact that they think more work is necessary than you do, or whether it is based upon a difference of view as to the cost of the work?

A. I am under the opinion that I have based my estimates on a larger amount of work than they do theirs.

Q. But you think it will not cost as much to do it as they do?

A. Yes, sir. For instance, for the harbors I had a harbor chart for each of the harbors, and then I took the latest Bulletin, number 22, issued by the Lake Survey, and the chief engineer's report for 1912. And from the charts I determined the area which would have to be deepened, and from the chief engineer's reports I got the cost price of doing the work at that harbor in recent years and I added to that cost in every case a considerable amount; and then also the description from the bulletin of what information that gave, I used; and in that way I made up the estimate of cost for each harbor, for all the streams that had been improved and would be affected by this lowering, such as Grand river, and the streams

off of Green bay, and the Rouge river and Black river and so on. And I added in those estimates generally 15 per cent. for engineering contingencies.

Mr. Wilkerson: I think I could proceed along here almost indefinitely and perhaps cover a great deal of space that I would not require, if we examined the tables and the figures.

Mr. Austrian: We will give you the tables.

Mr. Wilkerson: Q. What did you figure for the Galops Rapids of the St. Lawrence river?

A. The St. Lawrence canals, my information was based on an inspection I made along there in 1903, and from a couple of maps, one a profile map and the other a contour map, soundings, and made simply an approximation in the case of that work for those canals; but I had in mind this consideration: The Canadian Government is about—is advertising for bids for enlarging or for rebuilding the Welland canal for, as I understand, a depth of 25 feet on the mitre sills of their locks, and then they will proceed to improve all the St. Lawrence canals along the north side of the river, and while they are making those improvements it will add but very little more to the cost to provide for an additional deepening of 4 inches or 8 inches; whereas if you take the conditions that you have now and are compelled to make over the present locks and approaches to the present canals, the cost will be materially larger.

Q. Did you consider the canal, or did you consider the river itself at the Galops Rapids?

A. From the map that I had, it shows very little work to be done in the river section for the approach of the canal.

Q. It is in the rapids itself, not the approach to the rapids?

A. For the boats going down the stream. As a matter of fact, I did not give much weight to that part of the navigation.

Q. Do you know the purpose for which the Gut dam was constructed by the Canadian Government?

A. I have been under the impression that that work was done for water power development mainly.

Q. Do you know that they have been working in the Galop Rapids for years there to create a channel for down-bound vessels?

A. They were working in some of those channels, at the time I made the inspection.

Q. You didn't figure any—

A. Not for that particular.

Q. Any expense for that?

A. No.

Q. And so far as the Canadian canals are concerned, you figure that they are about to reconstruct a good many of their canals, and that they could take into consideration this diversion at Chicago and do it more cheaply now than they could in the future.

A. Yes, sir.

Q. But if acting upon the situation it is, in view of the situation with respect to that which exists between Canada and this country, it would be necessary for this work to be done at some time in the future, after this contemplated work is already accomplished; that is to say if they refused to do it now, the expense would be a great deal greater than if they did it at the present time, wouldn't it?

A. It would but then they are placing their improvements for such a draft that it will be a long time before the United States Government meets that with an equal draft in their channels and locks and canals on this side. The Canadian canals are not uniform at all as to possible draft.

Adjourned to Friday, July 25th, at 10:00 o'clock A. M.

Friday, July 25, 1913, 10:00 A. M.

JOSEPH RIPLEY, resumed the stand for further examination and testified as follows:

By Mr. Austrian: Q. Mr. Ripley, since the adjournment on yesterday did you go over your estimates that you referred to in the course of that examination with reference to the improvements, or allowances for improvements in the St. Lawrence river?

A. I have.

Q. You wish to correct the answer that you made to a question put to you on cross-examination with reference to having included any amount in that estimate for contemplated improvements in the St. Lawrence river?

A. The estimates for damages to the St. Lawrence—or to the Canadian canals, which includes the St. Lawrence and the Welland, I estimated a lump sum of $200,000 for the river improvement in the rapids, and in the isolated places.

Q. And that amount was included in the statement which you furnished yesterday, was it?

A. The one and a half million dollars.

Q. Directing your attention to the report of the International Waterways Commission, with reference to the time and difficulties to be encountered in changing, deepening and making improvements upon these various waters referred to, will you kindly give us any views that you may have with reference to the statements therein contained.

A. The work necessary to be done to obtain an additional clear depth of 4 inches through the St. Mary's river, the foot of Lake Huron, the St. Clair river, Lake St. Clair and the Detroit river would take one year and would not necessarily interfere with navigation to any serious extent; and for the eight inches' deepening, the time would be practically the same. For the deepening of harbors, the period of time necessary in order not to materially interfere with navigation would be from one to three years. Some harbors could be finished in one year; others would require two years and a few of them three years.

Q. The report of the Commission, I believe, contains these statements that it would take many years to make these improvements, and that they would in the course of construction seriously interfere with navigation?

A. That meaning is implied in their report.

Q. And to the extent indicated by you in your previous answer, your views differ from those of the Commission?

A. Yes, sir.

Cross-Examination Resumed by Mr. Wilkerson.

Q. Speaking of the construction of canal locks again, Mr. Ripley, where in the case of the Panama canal is there the least depth, is it at the floor of the lock?

A. The mitre sills of the lock.

Q. Is there a structure there corresponding to the breast wall or platform below the mitre sill, in the case of the Panama Canal?

A. I can't say as to what the construction has actually been as to that particular.

Q. How about the other lock at the Soo?

A. The lock at the Soo?

Q. The others besides the Poe Lock?

A. The Weitzel Lock, as originally constructed, had a breast wall of about 5 inches, 5 or 6 inches, built upstream

of the upper gates to protect the upper mitre sill of the lock, and there was no construction in the lock for protecting the lower mitre sill, and a ledge of sandstone rock was left at the lower entrance, which was a foot higher than the sill.

Q. Who designed that lock?

A. Alfred Noble.

Q. In the plans that you prepared for the locks at the Panama Canal, was the structure corresponding to this breast work contemplated, did your plans show it?

A. We probably would have provided some protection for the mitre sill.

Q. What is the fact about your plans?

A. Some of those minor details we had not taken up and worked out at the time that I left. It was the main features ot the lock walls, and the culverts and the gates that we had finished.

Q. But you probably would have put in a structure of that kind?

A. Yes, sir.

Q. Was that ledge of rock, in the case of the Weitzel Lock to which you have referred left there specifically for the same purpose that the breast wall in the case of the Poe Lock was constructed?

A. It was intended to serve that purpose, but beyond that the depth which had been made in the canal above the lock was 16 feet, and the same on the approach below the lock, it was 16 feet; the depth on the sill being 17 feet.

Q. That is a customary method of construction locks is it not, to provide a breast wall, platform, such as the one you referred to in the construction of the Poe Lock, with the depth a little less than that on the floor of the lock?

A. In the New York State Barge Canal construction, the top of the mitre sill is the same height as the top of the mitre wall for the upper gates, and we have no protection for the lower sill.

Q. Those are for small boats, are they not?

A. The width of the lock is 45 feet, and the depth on the sill is 12 feet.

Q. Where you are dealing with large boats, on the lakes, or with ocean vessels, there is an element of danger to the floor of the lock which must be looked out for in some way?

A. You mean the floor of the lock? There is no protection to the floor of the lock, for instance of the Poe Lock, or the Canadian Lock at the Soo, excepting at the lower platform at

the lower end of the Poe Lock, and none at the Canadian Lock. Upstream, the depth over the mitre wall of the Poe Lock would be the same as the depth on the floor of the lock.

Q. The point of it is: This whole matter about construction of the lock and the way in which the floor of the lock is protected, is a matter of engineering question?

A. The protection of the mitre sill is important, but in the Poe Lock the upper sill is protected by a breast wall, which is some 6 inches higher than the sill; and then there is the mitre wall, which is the same height as the mitre sill practically, and then for the lower sills, the platforms that reinforce and back up the sill could be made as high as the sill, or a little higher, and the top of that sill anyway is either 2 or 4 inches below the elevation of the lock floor, so that the lower sill of the Poe Lock is amply protected without that outer platform.

Q. Is there anything you wish to add to the answer to the question with reference to the purpose of this breast wall in the Soo Lock? I would like to have you state fully your idea as to the purpose of that.

A. For the Poe Lock, with the down bound traffic, being the loaded traffic to the full depth to which the boats can load, and the up bound traffic being most of it light, the up bound traffic only being about one-third of what the down bound traffic is, I do not believe that that lower platform below the lower guard gates of the Poe Lock is necessary for a protection to the lower mitre sill of the lock or the floor of the lock.

Q. I beg your pardon, but that does not answer my question. What do you think the men who put it there had in mind when they put it there? What was their object in having it there?

Mr. Austrian: I object to that.

Mr. Wilkerson: I ask your opinion as an engineer what the men had in mind when they put it there?

Mr. Austrian: I object to that as calling for the mental operation of someone else.

Mr. Wilkerson: The very thing you did all day yesterday.

Mr. Austrian: We were asking for his mental operation, not someone else's.

Mr. Wilkerson: All right, if he can answer it.

A. When the Poe Lock was first built, the platform below the mitre sill was not a part of the original construction and this lower, this outer platform which is higher than the lock

floor by about 4 inches was placed there as a protection to the lower mitre sill, I take it; but afterwards it was found that that sill could be better protected, and it was necessary to protect it by building the platforms which I have mentioned in my former testimony, platforms which were about 30 feet long on the axis of the lock.

Q. When that was constructed, as a matter of fact wasn't the mitre sill below the level of the lock floor?

A. The lock floor on which the mitre sill rests, and covers the area between the gates—

Q. The main lock floor?

A. It is the main floor of the lock at that end of the lock, between the intermediate and the lower lock gates. The elevation of that floor is 18 inches lower than the floor of the lock from the upper end of the recess of the intermediate gates to the upper mitre wall.

Q. As a matter of fact, isn't the mitre sill protected fully by the manner in which the lock is constructed, without this breast wall?

A. In my opinion it is.

Q. By reason of its position with relation to the other parts of the floor of the lock?

A. Yes, sir.

Q. And therefore it is not the purpose of the breast wall to protect the whole lock floor; that is the thing we have before us here. If the mitre sill is protected some other way—

A. I do not believe that platform is necessary for protection to the floor or mitre sill of the Poe Lock.

Q. The result of it is you do not think it is necessary, and you think whoever put it in there did something that was wholly useless?

A. Yes, sir.

Q. That is your opinion about it?

A. Yes, sir.

Q Do you know who was responsible for putting this unnecessary thing in there?

A. That was built under the direction of General Superintendent E. S. Wheeler.

Q. And General Poe?

A. General Owen Poe.

Q. And the plans, as you understand it, were approved by the Chief of Engineers of the United States?

A. Yes, sir.

Q. And so with respect to the necessity for that breast wall,

your opinion simply differs from theirs, that is the net result, isn't it?

Mr. Austrian: Wait a moment: He does not know what their opinion was.

Mr. Wilkerson: Q. Your opinion differs from what they did?

A. Yes, sir.

Q. From their opinion as evidenced by their acts?

Mr. Austrian: I object to "their opinion as evidence by their acts." Acts do not necessarily construe an opinion.

Q. Your experience as I understood you yesterday has been largely at the Soo.

A. I put in about 30 years there.

Q. What work in the St. Clair river have you had to do with personally?

A. None of the work in the St. Clair river has been done under my direction.

Q. Or the Detroit river?

A. Or the Detroit river.

Q. Have you ever had anything to do with any improvements in Lake Erie?

A. Only in connection with the Barge canal work, the east end of the lake.

Q. I am speaking of United States work?

A. United States work, no, sir.

Q. How about Lake Ontario?

A. Only as far as the Barge canal work at Oswego is concerned.

Q. How about the St. Lawrence river?

A. Nothing of that work.

Q. You have gone up and down the St. Lawrence river have you with considerable care?

A. I made an inspection trip with Superintendent Boyd of the Canadian canal at the Soo, and the Superintendents of the Canadian canals on the St. Lawrence river in 1903.

Q. Just what kind of an inspection?

A. Why we visited the different canals along the St. Iawrence river and the Trent Valley canal, and made an inspection of the construction which was under way or had been done on the canal prism, and the locks and regulating works.

Q. Did you ever make any study of the effect of the Gut dam?

A. No, sir, I have not excepting as I have read in the re-

ports as to the effect of that dam raising Lake Ontario about $4\frac{1}{2}$ inches.

Q. Your association with Mr. Noble lasted how many years?

A. I was his assistant for six years at Sault St. Marie, and then have been associated with him on that International Board for the Panama Canal.

Q. He is an Engineer of eminence, is he not?

A. He is the leading engineer of the United States, possibly of the world.

Q. A man whose opinion upon engineering propositions is entitled to great weight among engineers?

A. It certainly is.

Q. I am still left just a little in doubt as to exactly what you had in mind in your testimony about the reading of the water gages. Just what did you intend we should conclude from what you said as to the accuracy of the work of the Lake Survey?

A. With reference to water gages?

Q. Yes?

A. Why that for particular readings of the staff gages and of short periods of the self recording gages, that entire confidence as to their accuracy within one or two-tenths of a foot could not be placed.

Q. That is as to particular readings?

A. Yes, sir.

Q. And for short periods?

A. And for short periods.

Q. You do not—

A. For short periods; the case I cited with reference to the bench mark at Sault St. Marie, as I remember it, covered a period of nearly two years.

Q. That was a long while ago?

A. In which there was a settlement of the bench mark on the pier to which this gage was referenced, which took place during that period.

Q. That was before you went to the Soo wasnt' it?

A. Oh no, that was while I was there.

Q. In what year was it?

A. It was along in the eighties as I remember.

Q. You found this condition?

A. Yes, sir.

Q. After that there was nothing like that happened while you were there, was there?

A. We used to find some settlement in that gage on the Southwest Pier nearly every time we checked it up, a slight settlement.

Q. But you looked after it a good deal more carefully after you went there?

A. Well no, I was there from 1877 in that work and that gage was not checked up as often as it ought to have been.

Q. Isn't it true that there is a great deal more care taken in a matter of that kind than 30 or 35 years ago?

A. Yes, sir, the importance of it is more fully recognized.

Q. As navigation has increased, and vessels have increased in size, it has become more and more important that these readings be taken accurately, hasn't it?

A. Yes.

Q. As a matter of fact the Lake Survey has appreciated that necessity and has kept up with it, has it not?

A. Why it tries to, yes, sir.

Q. You say you think so far as particular readings are concerned, it might make a difference of as much as 1/10 of a foot or 2/10 of a foot?

A. More than that in particular readings.

Q. In particular readings. Uses made of these gage readings in drawing deductions by the engineers of the Government Service. Take for instance in determining the effect of the diversion at Chicago, they made use of these observations.

A. Yes.

Q. Taking the average level of the lake over a long period?

A. Yes.

Q. You had occasion, at one time or another, to study their reports on that subject?

A. Yes, sir.

Q. It never occurred to you that having in mind the periods with which they were dealing, the long length of time over which the observations were taken, there was anything in the possible mistake as to a particular reading, or the condition as to a short period that would in any way materially affect the conclusions that they drew from their observations, did you?

A. It depends on how much weight you put on the word "material."

Q. I mean it would not as to that make a difference of 2/10 of a foot, would it?

A. For instance, the staff gage at the head of the South-

west Pier is located about a mile from the canal office; and the daily noon reading has been taken on that gage ever since it was established in 1870, and during the winter season, it is a long cold trip up there and I have known the observor, instead of going up to the head of the pier, to go part way up and simply make a guess what the reading was.

At other times I have seen when there was a storm, the zero of the gage would be covered with water, and the observor would have gotten wet if he had tried to take a measurement, and he simply guessed how deep the water was over the zero of the gage. He might have guessed within two inches or six inches of what was right.

Q. Those are particular observations?

A. Yes, sir. But this was at the Soo where the conditions are a great deal more favorable for getting close accurate results than they were at the other stations. I have been told by parties who presumably knew the facts of the case, that at Marquette in those years of the seventies and eighties, the zero of the gage was very seldom checked up by level readings from the bench mark.

Q. Were you ever told about anything that happened at Marquette after the year 1890?

A. No, sir.

Q. Ever told about anything that happened at the Soo after 1890 of the kind that you have—

A. I was familiar with what was going on at the Soo until 1906.

Q. Now suppose for the same lake, you had two gages that had been read over a long period of time, and the average lake level was, for all engineering purposes, precisely the same. That would indicate to you that any errors of observation in isolated cases with reference to a particular gage would be balanced by other errors of the same kind in such a way as to be practically eliminated, as a practical proposition?

A. They might be balanced or might not, and the error in one or several of the individual readings might not affect the general mean of all the readings for a period. And again it might be that the readings would be affected as to the general mean to some appraciable extent.

Q. Are you familiar with the Haskell self-registering water gages used by the Lake Survey?

A. Yes, sir. Two were established at the Soo while I was there.

Q. Have you had occasion to observe the results of the use of those gages?

A. Yes, sir.

Q. When were they installed there?

A. Well, sometime in the late nineties.

Q. A self-registering gage of that kind would rather eliminate this element that you mentioned, in going up to read the gage, wouldn't it?

A. They keep up the practice at the Soo of reading both the gage at the head of the Southwest Pier and the gage on the Northeast Pier below the locks daily, the noon reading, as it is necessary to see that these self-registering gages are in working order and are running each day.

Q. Is it not a fact that there are gages upon the masonry of the Poe Lock, both above and below the lock.

A. We had a gage painted on the Poe Lock and on the Weitzel Lock masonry above and below, to indicate the depth on the sills.

Q. With reference to the use of the four gages in reaching a conclusion as to the mean elevation of the lock, as distinguished from determining the mean elevation of the lock from the observations of a single gage, assuming the same degree of care on the part of the gage reader in both cases, how much of a difference in your opinion would it make in determining the mean elevation for a given year whether you had four gages or one?

A. Possibly it might make a difference on a lake like Michigan or Huron or Erie or Ontario of 1/10 of a foot.

Q. You say possibly it might?

A. Yes, sir.

Q. You have never made any study of the gage readings where there has been more than one gage on a given lake and where the readings have been taken for a year for the purpose of seeing whether there has been anything like a difference of 1/10 of a foot, have you?

A. I have never had a practical demonstration of the gages being established on a lake in that way and the readings taken, and then the mean of the four compared with any one of the four.

Q. It would be a pretty fair check, if you had two gages on the same lake and you took the mean level for a given year and found that they tallied exactly; that would show you could get it very nearly from a single gage, wouldn't it?

A. Not necessarily.

Q. It would show that if there was anything wrong with one gage, the same thing was wrong to precisely the same extent with the other gage, which would be rather an exceptional situation.

A. The elevation of those gages, to my mind, should be accurately determined by lines of precise levels, and not depend upon the determination of the elevation of one gage from another by transferring the water surface readings. Otherwise, if the determination is made by transferring to water surface readings, you would not get any difference probably between the readings between two gages.

Q. Is it your opinion that a line of precise levels from Whitefish Bay to Duluth, for example, would give a higher precision for the level at Duluth than if you were simply to treat the surface of the lake as level?

A. I think it would; yes, sir.

Q. If Lake Superior should give one result extending over a period of a number of years, and the line of precise levels were to give another, which one, as an engineer, would you regard as entitled to the greater weight?

A. The one that was referenced to the precise level determination.

Q. Where in the work of the Government has the necessity for such lines been recognized?

A. It has not been recognized in the past. There is no reason why it should not be in the future, if that is the proper way to treat the question.

Q. My proposition is, or my question is, in all the vast work of the Government engineering service, you know of no instance in which the necessity of that has ever been specifically recognized?

A. It has not been, where the work has simply been improvement work, deepening the channels and so forth like that, but when you come to make a scientific study of a problem, I believe that you should try to secure the greatest accuracy.

Q. How about the coast and geodic survey, do they recognize it?

A. I don't know whether they have followed that plan in that particular or not. I doubt if they have.

Q. Where it has been regarded as important by the Government engineers to take readings of two gages for the purpose of determining lake elevation, hasn't that been in connection with the study of storm conditions?

A. I don't know the reasons which have prompted the

officials on the Panama Canal work to have a series of readings taken around Lake Gatun, but they are having such readings taken there.

Q. Are you familiar with the studies made by Mr. Blunt of Toledo concerning storm conditions of Lake Erie?

A. I have read a number of scientific papers relating to the problems pertaining to the lakes, lake levels, but I do not recall whether I read that gentleman's articles or not.

Q. I assume that as a matter of course you have made no detailed study of the problem of determining the effect upon the lake levels of the diversion of the water from the lakes at any particular point?

A. No, I have been just interested in the problem in a general way.

Q. You have made no detailed study and have no information as to the extent to which these isolated and fragmentary errors of observations of gage readings would modify the results which have been reached and certified to by the Government engineers in that respect?

A. No, sir; I have not.

Q. Now, you spoke of the change in the reference plane. I think you said that was made in 1903, wasn't it?

A. It was made for the project of 1903, but made previous to that.

Q. Now, it appears of course from the Government records, but I wish you would state it again so we may have it here in a convenient place, just what the project of 1903 was?

A. The project of 1903 was for the improvement of the rivers and lake channels between Duluth and Buffalo, and Chicago and Buffalo, for the purpose of securing channel depths of 21 feet in ordinary material, soft material, and 22 feet on boulder and rock shoals.

Q. There was a preliminary report of the Chief of Engineers?

A. Yes, sir; the project had to be submitted to the Chief of Engineers.

Q. That is to say, I understand this was the course followed there as is the case for any improvements, in these projects, is it not?

A. Yes, sir.

Q. First there is an Act of Congress?

A. Authorizing a survey by us.

Q. Authorizing a survey by you, and requiring the Chief of Engineers to submit a report?

A. A report, yes.

Q. That report is transmitted by the Secretary of War to the President and he transmits it to Congress, and Congress then appropriates for the work?

A. I don't know as it is transmitted to the President by the Secretary of War; maybe it is transmitted directly to Congress. That is a minor detail.

Q. Did you prepare the estimates upon which some of these improvements were authorized?

A. The surveys were made by my assistant, Mr. Rohert, and the computations were made by his force and himself for the quantities, and he fixed upon the unit prices for the different classes of work and submitted a report to me. And then I revised the unit prices to a certain extent and transmitted the report as mine to the engineer officer, with such recommendations as I saw fit to make.

Q. Just how were those computations made?

A. The surveys were made on a rectangular system. For soft material, the soundings are taken 10 feet apart, with the cross sections generally 100 feet apart, sometimes 25 and sometimes 50. On the rock sections, the soundings are taken 10 feet apart, both on the cross sections, and the cross sections being 10 feet apart. And then the computations are made with reference to the surveys developed by those soundings, the levels and the grade planes and side slopes fixed upon for that particular location.

Q. How much time did it take you and him to prepare these estimates for that work? I mean the surveys and estimates for the work.

A. The surveys for these estimates were made in connection with the regular routine work of the river party, river survey party, and as I remember, the surveys extended over a period of about a year; some of them taken in the summer-time, most of them in the winter-time.

Q. And in doing the computation necessary to make the estimates, how much time was consumed?

A. Well, they were practically worked up so that when the survey, the field work was finished, it was only a very few days after that when the office work was completed.

Q. Occupied all the time during a year?

A. Practically so.

Q. In order to get the accurate results which were necessary for an estimate of this kind, you regarded the method that was used there as necessary?

A. Yes, sir.

Q. How much did that work cost all together?

A. As I remember the project, it was for the St. Mary's river in the neighborhood of five or six million dollars; but that is simply stating from memory.

Q. How long did it take to do it?

A. The contract for the West Neebish work was awarded in the spring of 1904 and the channel was opened in the latter part of July or early in August, 1907. The Middle Neebish work, or the work on the Middle Neebish route was awarded in 1908, spring of 1908 and it was finished either in 1911 or 1912.

Q. Speaking of the Middle Neebish, in the St. Marys River, there is a wing dam constructed there. wasn't there?

A. There was a dam built—cast up by the dredge making a cut from the head of the dyke, the dyke running parallel practically to the improved channel through the Middle Neebish Rapids, on the north side of the channel; and this dredged cut extended from the head of the dyke over to the foot of Sugar Island.

Q. Was there a wing dam running from the dyke to the island, shutting off the flow in the rapids?

A. It was intended for that purpose but it didn't accomplish it. The dyke washed away in places very soon after it was constructed and in two or three years none of the dyke could be seen above the water surface.

Q. By whom was it designed?

A. By Mr. Wheeler.

Q. And who built it?

A. A dredge was employed by the working hour, and the expense, as I remember it was about $14,000 for that particular dyke.

Q. It was built under your supervision of course?

A. Yes, sir, I had charge of the river work at that time.

Q. I want you to state just a little more in detail what it was that was thought the construction of that dam would accomplish?

A. The object of that dam and of similar dams at the Little Rapids was for the purpose of maintaining the pool level of Hay Lake, and the pool level of the point between the head of the Little Rapids and the foot of the lake.

Q. It was a compensating work then?

A. It was intended for a compensating work.

Q. You were familiar with the plans for this improvement?

A. I was, yes, sir.

Q. You understood the purpose for which it was intended to construct the dam?

A. I understood the purpose but I did not approve of the method.

Q. That is you thought that the compensation could not be made in this way?

A. I didn't think it desirable to make it.

Q. Why didn't you think it was desirable?

A. On account of maintaining the swift current in the channel at the Little Rapids at the Neebish and at Sailors Encampment. Of course that particular dyke would not have affected Sailors Encampment particularly.

Q. That is one of the effects of all works of that kind, is it not?

A. Yes, sir.

Q. To diminish the cross section of the river and therefore increase the current?

A. Yes, sir.

Q. So that that always has to be taken into consideration in work of that kind as to whether in compensating, as far as level is concerned, you do not get a bad condition as far as the velocity is concerned?

A. Yes.

Q. Wouldn't there be the same result as to effect upon the current in your proposed plan for the St. Clair River?

A. No, sir, in that case the current would be lessened at Fort Gratiot, where it is now the swiftest in the river.

Q. How about Stag Island?

A. That would not be materially changed, not necessary to materially change it. I do not believe in simply putting in one dam for one of the lakes. If you are going to put in compensating or regulating dams, they should be for all the lakes.

Q. The fact of it is that in connection with this 1903 project, there was a dam constructed which some of the Government Engineers—

A. No, not in the 1903 project. That was in the earlier project. These dykes were built at the Little Rapids and the encampment under earlier projects.

Q. There was one dam?

A. Yes, sir.

Q. There was a wing dam built in the Middle Neebish

which it was thought by some of the engineers at that time would compensate?

A. Yes.

Q. But which as a matter of fact failed to accomplish its purpose?

A. Yes, sir.

Q. That is a fact, isn't it?

A. Yes, sir.

Q. And the fact is that it was opposed by you because it would increase the velocity of the current?

A. Increase or maintain the original velocities before the improvements were undertaken.

Q. So this matter of compensation is, after all, is it not a pretty complicated engineering problem, in which you do have to take into consideration, not merely whether you are going to maintain your level or get your higher level, but also the effect which you are going to have on the current?

A. It is a very complicated problem, but it can be solved in my opinion for the lakes and connecting rivers.

Q. That is to say you think you have reached a solution of it, that is your best judgment about it?

A. Yes, sir.

Q. At a total cost of how much now for compensation, for all the lakes?

A. The cost would be somewhere between the range of One and a half Million and Five Million Dollars.

Q. And in your opinion as an engineer would the cost when the work was completed, I mean the money paid out by the Government, be nearer a Million and a half, or nearer Five Million Dollars?

A. I believe it would exceed $3,000,000.

Q. You believe it would exceed $3,000,000?

A. Yes, sir.

Q. And in this do you include compensation down the full length of the St. Lawrence River?

A. I do.

Q. Allowing how much for compensating works along the St. Lawrence?

A. The estimate for the St. Lawrence River ranges between $200,000 and $1,000,000.

Q. And in your opinion the amount that would be actually paid out by the Government before the work was done would be not less than how much?

A. It depends on how much the work would benefit water

power development, and what share of the work would be paid by the water power companies.

Q. Not for that purpose, but I mean just the expense to the Government?

A. It would probably be nearer the Million Dollars.

Mr. Austrian: Than the $200,000?

A. Yes, sir, than the $200,000.

Mr. Wilkerson: My question is this: Of course you have in mind the practical experience in matters of this kind, based upon observing appropriations over a long period of time. What I wanted to get at is your best judgment as to how much money Congress would have to appropriate for that work before they got through. You think not less than a Million Dollars, as far as the St. Lawrence is concerned?

A. Nearer the Million than the $200,000.

Q. Would it in your opinion be less than $750,000?

A. Probably not.

Q. That is you would not want to go on record, if you were called upon to estimate to a committee of Congress, as to how much it would cost to do that work so that they might make an appropriation, you would not want to say they would have to appropriate in the end less than $750,000 for that, and stake your reputation as an engineer on that proposition?

A. For the St. Lawrence River I have no figures made itemizing the cost for each locality where a dam would be necessary; but I believe my total estimate for all the rivers would build all the dams necessary. For a recommendation to the Government to make an appropriation on, the problem would have to be studied out with great care as to what amount you were going to raise the mean elevation of the lakes, whether it was 4 inches or 8 inches or a foot or whatever the amount would be; and then consider the best type of dam to be built at each locality, and the cost of building such a dam at that locality.

Q. Just how detailed has been your study of the St. Lawrence?

A. The St. Lawrence, the least of any of the streams.

Q. Have you made such a study of the conditions on the St. Lawrence that if you were called upon by a committee of Congress to make an estimate of the cost of doing this work, upon which it could act officially in making its appropriations for an improvement of that kind, you would feel that

you could give to the committee the detailed information which it ought to have to act on your recommendation?

A. If the stenographer will read my last answer, I think that answers your last question.

(Answer of the witness read.)

Q. That is to say you do not feel that you have made that detailed study necessary for a purpose of that kind?

A. No, sir, I have not.

Q. What consideration if any did you give to the situation at Farrans Point?

A. Nothing more than the general detail as to the other locations at the head of rapids along the St. Lawrence River.

Q. What excavation did you estimate as necessary in the river at that point, paralleling the canal?

A. As a matter of fact I do not think that any excavation would be necessary at that point.

Q. Why not?

A. Because you are diverting a certain number of cubic feet per second flow from the St. Lawrence River by the canal at Chicago. Now you want to maintain the level of your pool above the rapids for that location; and the chances are that it would be a dam that would reduce the cross section, but having a movable dam that you could practically have the same cross section that you have now, if it was necessary.

Q. Not the pool though above the rapids, but in the rapids themselves.

A. These dams in my opinion would be located near the head of the rapids all the way along the river.

Q. What fall does the river take at Farrans Point?

A. That is a detail; I have a map which will show it, but I do not recall it offhand.

Q. You may refer to the maps; we want the fact at this point, that is all.

A. It is a small amount as I recall it. (Referring to map.)

Q. (Question read as follows: "What fall does the river take at Farrans Point?")

A. 3 to 5 feet.

Q. Do you know how much money has been expended by the Canadian Government on the St. Lawrence?

A. I read the reports of the department as to the expenditures of the Canadian Government on the Canadian canals and on the St. Lawrence River, but I could not recall.

Q. That has been a very large sum hasn't it?

A. Rather large.

Q. This whole problem of navigation on the St. Lawrence has been a very complicated problem, has it not?

A. It has probably been made so, maybe unnecessarily.

Q. You mean by the Canadian Government?

A. By the engineering and the government method of proceedure.

Q. Now I want your full view on that, because that involves a criticism of the engineers of both this Government and Canada, and I want your full view on it. In what respect do you think they have made a complicated problem of it when as a matter of fact it was a simple problem.

Mr. Austrian: You are incorporating in your question something he did not say. He did not say it was a simple question; he said perhaps they made it more complicated.

Mr. Wilkerson: I will accept your modification.

A. It is simply like this: At the time when I made that inspection in 1903, I received certain impressions about this or that particular feature of the work. Now I can't recall what those impressions were today. That was made 10 years ago. But I can recall what my final judgment and conclusion was with reference to it.

Q. So that you are not prepared to state a conclusion which is based upon facts and data that you are able to present in connection with your conclusions?

A. With reference to that particular question I am not.

Q. Is that same thing true about some other impressions which you had about things that happened 10 or 15 years ago?

A. Not necessarily so.

Q. But it is about the St. Lawrence River?

A. It is for that feature of it, of the St. Lawrence River improvement.

Q. If the same degree of care were given to the preliminary study with reference to these contemplated improvements about which you have testified, which you gave in connection with the estimates submitted for the St. Marys River, how long would it take to present a detailed plan for these proposed improvements, upon which the action of Congress could be predicated.

A. For St. Marys River, my estimate is based on an amount of work to be done by different plant, and not upon yardage, and it would be impossible to present by drawings any such project as an amount of work and the exact work to be done. But you can take the final estimate soundings of those chan-

nels and estimate and locate from the soundings the probable places where improvement work would be done rather than at other places. The exact amount of work to be done would have to be determined by sweeping the channel with raft bars. If you were to look at the soundings for instance of any of the channels of the St. Marys River that I have here—I didn't bring them all but I have a section, for instance, of the Middle Neebish and of the West Neebish and of Sailors Encampment on the rock sections.

Q. You have produced here one of the sheets which illustrates the manner in which you have made some of these estimates. Just explain, so that we will understand what you have done.

A. This is on the rock section at Middle Neebish, and the improvement was for a depth of 22 feet.

Q. This is one of the—

A. This is the final estimate soundings for that work, final estimate 1910.

Q. This is one submitted when you were with the Government?

A. No, sir, this has been submitted at the request of Mr. Adcock.

You take the soundings: The decimal shows the point between the tens and the feet; that is 24.4, 24.8, 24.6. You look along here, and you do not find much of anything below 24. There (indicating) is 25.6, 25.6, 25.9, 25.7, 25.2. You don't find any of them much below 24. Some are over 27 in that section.

Mr. Austrain: That means the depth?

A. The depth from that water plane.

Mr. Adcock: From the reference plane?

A. From the reference plane of the improvement down to the bottom of the bed of the river. They wanted 22 feet in the clear, and here you see they are getting from 24 to 25 feet, 2 or 3 feet, some cases 4 feet below the required grade. The chances are if you wanted to deepen 4 inches or 8 inches along over that section, you would have very little work to do.

Q. That is the reference plane which you mentioned yesterday, in connection with the 1903 project of the St. Marys River?

A. The grade plane mentioned.

Mr. Austrain: Q. All these plats, these reference plats that are technically described here, they are in the Government Survey Office?

A. For the St. Marys River channel, the Detroit River.

Q. For all the navigable rivers?

A. Where they have to do work under that 1903 project. As a matter of fact, in that Middle Neebish work and the Encampment work, the Encapment work was in limestone, and Mr. Sabin told me that the contractors build 3, 4 and 5 feet below the required grade plane to be secured, and put in heavy charges of dynamite so that they virtually pulverized the material. In the Middle Neebish the material came out as sand instead of rock.

Mr. Wilkerson: Q. How much time have you spent in preparing your estimates?

A. Between 20 and 30 days.

Q. What do you mean by raft sweeping

A. The raft we used on the St. Marys River work was built of timber, 12 by 12 inch timbers with board platform. It was 130 feet in length, 20 feet in width, and from that raft along the center line of it was suspended eight bars, the bars being about 22 feet long each; they overlapping at the ends; and then we would run out a head line, a kedge to hold the raft in position as to up and down-stream, and then put out two kedges on each side, one from either end, and then could pull it across the stream by windlasses on the raft, or we could push it with a tug, depending on the location.

The bars were suspended by chains from windlasses. Each bar had a chain at each end of the bar and we could lower those bars to any depth that we wished, and then by swinging the raft slowly across the stream in this position (illustrating), if the stream was coming down this way (indicating), we would locate the material that was above the grade plane.

Q. How much above the grade plane?

A. Well on the Middle Neebish work, on one contract we had a strike, and sent the diver down, and he brought up a little tin can, and the contractor said he kicked on that.

Q. Was the work accepted if a point of rock projected up as much as an inch?

A. I required one of the contractors to tow a drill boat from the Soo down to the Middle Neebish, to remove a piece of solid rock that was a quarter of an inch above grade.

Q. The contractors thought you were pretty hard, didn't they, sometimes?

A. Sometimes, but they all wished me well.

Q. But you were going to make sure that you had all the water in those channels that you were trying to get?

A. Yes, sir.

Q. And even to within less than an inch, the contractor would take out what he had agreed to do?

A. The contractor was required to remove all material above the grade plane so that the raft bars would swing clear without striking.

Q. You have spoken about a contractor, either through some provision in his contract or through some custom, the exact facts about which you seemed to be a little in doubt, was allowed to excavate below the grade plane?

A. They were permitted to excavate to whatever depth they preferred below the grade plane.

Q. Now having in mind that those channels might, at some future time, be further deepened, would it be to the advantage or the disadvantage of the Government to let the contractor do that?

Mr. Austrain: I object; that is a matter of argument. That is a policy that the Government has evidently adopted, and it is not for the witness to pass on.

A. It would be to the advantage of the Government to have them work as much as they would below the paid grade plane.

Mr. Wilkerson: Q. Where there was stone, the broken stone would be more easily taken out than solid stone.

A. Yes.

Mr. Austrain: Q. They are getting extra pay for that work below the grade plane?

A. Yes.

Mr. Wilkerson: Q. I refer to this report of the International Waterways Commission, page 72 of that report, which is Appendix 1, and is the report upon the Chicago Drainage Canal by the Commission January 4, 1907. In paragraph 25 of this report, I direct your attention to the statements: "Careful estimates have been made of the cost of deepening the channels between the lakes 1 foot;" in the preparation of your testimony have you examined those estimates there referred to?

A. No, sir, I have not been able to see their estimates in detail.

Q. I notice the next statement: "To deepen the Detroit River is estimated to cost $4,115,430." Are you able to state the fundamental difference between the estimates made by the International Waterways Commission and the estimates which you have made?

A. I imagine that they based their estimate on the cost of excavating the material 1 foot in depth over the area of all the shoals which have been improved for the channels in the Detroit River.

Q. You made no allowance then for the shoals?

A. I certainly did, but I took the conditions as they are now in those channels, the depth of water as left by the contractors under the last contracts and then made my estimate of the cost of securing an additional 4 inches and an additional 8 inches by using the raft to locate the material that is above the grades for those depths; and then removing the material by a diving outfit, or with dredges, or where necessary to use a drill boat, and drill and blast the rock that would be solid.

Q. That is what they call a cleaning up?

A. Call it a cleaning up, yes, sir.

Q. Is there as much clear water under a vessel after this cleaning up process as there would be if the work was done clean?

A. The vessel could not strike with that additional clear depth any more than they do now, but there would not be the amount of water below the keel of the vessel that there is for the present conditions.

Mr. Adcock: That is for certain places.

A. Any of the places in the channel there; but that additional clear water has been secured without expense to the Government.

Mr. Wilkerson: Of course that additional clear water is helpful to navigation?

A. It is helpful to navigation in a way. They might run a little faster by having it, but still it is uncertain just where it is, so that as a matter of fact for practical navigation it cannot be utilized.

Q. Let me put this question to you: Suppose that the conditions were created where it was necessary to deepen these channels 2 or 3 feet. By that I mean suppose other people along the lake were allowed to take the water, or were to take the water as they are doing at Chicago; and not only Chicago taking it, but they commence to take it in Indiana and Cleveland and Buffalo and all places along there, so that it would be necessary to deepen those channels two or three feet. The expense of doing that could not be determined from your figurs by merely a process of multiplication, could it?

A. It could. One way of estimating the cost would be to

say if the levels of the lakes have been lowered a certain amount, say 1 foot, why then in order to secure a 25 foot grade or 24 foot grade in the future then there would be that additional foot of material to be removed and the cost of that would be a certain amount. And you could also treat the conditions just as the conditions are treated by me at the present time; that is you consider that the improvement was made, instead of 24 feet to 23 feet, and there would be no added cost then; and then go to work and secure the additional foot by this cleaning up process, which would be much cheaper in cost than it would to take out a foot of solid material.

Q. What is your estimate of the expense of deepening the Detroit River a foot?

A. I did not make an estimate for a foot.

Q. What is your estimate for four inches?

A. For deepening four inches, $30,300.

Q. How much?

A. $30,300 practically.

Q. To deepen the Detroit River four inches?

A. Yes, sir.

Q. How much to deepen it eight inches?

A. $103,200.

Q. Have you any views based upon your examination of this as to what would be the expense of deepening it a foot?

A. I have not. The cost would increase quite rapidly from the eight inches to the foot.

Q. Well, about how much, what is your best judgment now as an engineer as to the expense of deepening it a foot?

A. I believe that it would exceed $300,000.

Q. Why in your judgment should there be such a wide difference between your figures and that of the Waterways Commission as to the expense of deepening the Detroit River a foot?

A. Because they are basing their estimate on a foot of material being removed over the entire area of those shoals.

Q. Why wouldn't that be necessary?

A. Because they have got more than that foot of depth, from one to three feet below the grade plane now, and it is a cleaning up process.

Q. If the level of the lake was lowered a foot and you wanted to make the conditions at the bottom of the river precisely what they are now, it would be necessary to take out a solid foot, wouldn't it?

A. It would, but it would not be necessary to do it for pur-

poses of navigation in securing the additional foot clear draft.

Mr. Austrain: If you wanted to make that exactly as it is now, you would have to take a photograph of the bottom.

Mr. Wilkerson: My point is how much it would cost to make the bottom of the river, to leave the bottom of the river in precisely the same condition as it is, with the level of the lake reduced a foot.

Q. And you think their figures would probably be substantially correct for that, do you?

A. I don't know what unit prices they have used.

Q. Assuming their unit prices and yours are about the same, it would cost $4,000,000 to do that?

A. I have not made any estimate along those lines, but I presume that it would approximate the $4,000,000.

Q. You have no doubt that their estimates, on the theory on which they were made—

A. Were honestly made.

Q. So that as you understand it, the difference between yourself and the Government Engineers in the figures stated for the Detroit River grows out of the fact that you have made an estimate of merely the expense of shaving off, so to speak—

A. The high points.

Q. Shaving off the high points, whereas the Government Engineers have made their estimate upon the theory, right or wrong, that in view of what the Government itself may see fit to do with these waters in the future, the damage which results to the Government is the cost of taking out four solid inches.

Mr. Adcock: I do not think it appears in the record anywhere that there are any Government Engineers who have made any estimate on this case. I object to the question for that reason.

Mr. Wilkerson: I will change my question.

Q. As I understand it, the fundamental difference between yourself and the report of the International Waterways Commission is that you have made an estimate which involves shaving off the high points, whereas as you think their estimate is based upon the expense of removing 1 foot of material; that is the difference?

A. Yes, sir.

Q. Now, you spoke of the comparative expense of deepening 8 inches and deepening a foot. The cost would increase rapidly as the extent to which you deepen increases?

A. Yes, sir.

Q. Would that same thing apply between 1 foot and 2 feet?

A. Yes, sir, only more markedly.

Q. And from 2 feet to 3 feet there would be a still further ratio of increase?

A. Yes, sir.

Q. So that when you got up to a deepening of 2 or 3 feet, you would get to a very large figure?

A. You are getting to the solid material to be taken out, entirely.

Q. Now the next one of these rivers, or rather the next body of water in which the International Waterways Commission report says that it will be necessary to do something is Lake St. Clair and the statement is: "In Lake St. Clair, the full depth of the lake is now utilized, and any lowering of its surface involves the excavation of an artificial channel entirely across the lake, a distance of 18 miles, of which it has been necessary heretofore to artificially deepen only one-third."

I understand it to be your contention that that statement of fact is inaccurate?

A. Yes, sir.

Q. And upon what do you base your conclusions as to the correct facts there?

A. Upon the fact that the deepening of Lake St. Clair under the 20-21 foot channel project of 1892 or 1893 to be a channel 800 feet wide, dredged entirely across the lake with the exception of about a distance of a mile and one-eighth; and upon the further fact that since that channel has been improved, the passage of boats has stirred up the soft clay silt in the bed of the channel, and the currents and cross winds have carried that material and deposited it on the bed of the lake to the westward of the channel, so that at the present time the channel is from 1600 to 1800 feet wide and about 24 feet deep.

Q. I call your attention to the estimate made in the report of the International Waterways Commission of $1,080,720, as representing the expense of deepening the channel through certain places in Lake St. Clair?

A. And St. Clair River.

Q. And St. Clair River. I ask you whether or not in your judgment that figure is unreasonable upon the assumption that what it is contemplated to do is to take out a foot of material in those places, and without regard to whether that is neces-

sary for the particular purpose which we are considering here?

A. I have not checked that through as to the quantity or as to the unit price used.

Q. Assuming that the unit price—

A. And the quantity was a fair one.

Q. Yes.

A. And the computed quantities were correct.

Q. Yes.

A. I should say that that estimate was all right.

Q. You have made no estimate however yourself?

A. No, sir, because there was no material to take out excepting a little just below the St. Clair Flats Canal where it silted up and the shoal for about a mile and an eighth along at the opposite end of the lake at Grosse Point.

Q. That is in the shaving up process?

A. No, that means dredging for the boats that are moving there now. That channel has got to be deepened. They ought to deepen it two feet. You could make it two feet four inches at a very little more expense.

Mr. Adcock: You mean 4 inches, 4 or 5 or 6 inches?

A. 4 to 8 inches.

Mr. Wilkerson: Q. Now your estimate for the deepening of Lake Erie was made upon the same assumption as the estimate—

A. The estimate for Lake Erie is included in the Detroit River work. The channels would have to be lengthened for possibly a half a mile at the lower end of the Detroit River, on account of deepening an additional 8 inches.

Q. Did you include the approach to Toledo?

A. The approach to Toledo was included in the improvement, or the deepening for the Toledo estimate.

Q. Did you include the South Passage?

A. I did not include the deepening of the channels in Lake Erie.

Mr. Austrian: Why not?

A. The depth is greater than is being secured in the improved river channels already, or greater than with the present improved channels deepened an additional 8 inches. This is true for all the channels on the west end of Lake Erie.

Mr. Wilkerson: The report of the International Waterways Commission as to the deepening of the harbors in the United States is $2,000,000. What is your figure for that?

A. That was for a foot, you understand.

Q. Yes.

A. My estimate for the harbors of the United States for eight inches was $2,750,000 practically, but I included more harbors than they have.

Q. In that particular respect your figures are larger than those of the International Waterways Commission?

A. Yes.

Q. For a greater number of harbors?

A. Yes.

Q. What was your figure for the Canadian harbors?

A. For eight inches, $1,260,000.

Q. You made no computation for a foot?

A. No, sir.

Q. But it would be practically 50 per cent. more for a foot, or would it be more than 50 per cent. more?

A. Probably more than that.

Q. Probably more than 50 per cent. in excess of one million, what is it?

A. $260,000.

Q. That would be, for a foot it would be between two and three million dollars according to your figures?

A. Yes.

Q. I show you the map of Lake Erie, Williams' Exhibit 11, March 18, 1913, showing the South Passage from Toledo to Cleveland and ask you to examine that; and in the light of that examination to say whether you care to make any amendment to your statement of the depths and therefore the consequent necessity of deepening, even on your own theory?

A. The map or chart shows the soundings referenced to standard low water datum, which is 570.0. The improvements of the lower Detroit River for the Lake Erie elevation are referenced to datum 571.0. So that 1 foot should be added to these soundings to make them comparable with the soundings for the improved lower river channels of the Detroit River.

Q. Doesn't the chart show 18 feet or less at that stage?

A. 21 feet at the contours, so that it shows it is less than 21 feet. It may be more than 21 feet of the improved river depths.

Q. You had that in mind in stating it would not be necessary to deepen that passage?

A. I do not say it is not necessary to deepen that passage. It should be deepened for the present navigation, in order to make it safe in stormy weather; but if you are going to deepen it, the additional cost for securing 4 inches or 8 inches would

be less than one-fifth of the amount of money that should be expended on that shoal.

Mr. Austrian: You think it ought to be deepened two feet?

A. It should be deepened at least three feet if they are expecting a probable or about two feet deepening.

Mr. Wilkerson: Q. It is a fact that the deep draft vessels have to go around by the other passage now, do they not?

A. I understand so.

Q. When you made the estimate for Lake St. Clair, did you have in mind the points upon the lake in which there is some navigation?

A. Yes, sir.

Q. Wouldn't that make it necessary to do considerable work in Lake St. Clair then?

A. I estimated that under harbors.

Q. Under harbors?

A. Yes.

Q. In going through the Thames River wouldn't it be necessary to deepen the whole lake, that is to restore the equivalent conditions?

A. I included in my estimate what I consider the necessary deepening in the lake and at the docks around the shores of the lakes under the estimate for harbors, both in taking those for the Canadian side and for the Canadian harbors, and the American side for the American harbors; also for the Clinton River deepening, and up to Mt. Clements.

Q. Does the deepening of the harbor have any effect upon the piers in the harbor?

A. If you deepen to a large enough extent it would.

Q. Did you take that into consideration as an element in your estimate?

A. I consider a deepening of 4 inches or of 8 inches would not require any change in the piers or breakwaters of any of the harbors.

Q. Even when taken in connection with the deepening which has already been made the deepening which the Government may see fit to make in the future?

A. Taken with reference to what deepening has been made in the past by the Government, but without any reference to deepening which the Government may make in the future.

Q. But if, we will say, the Government were to deepen several feet in the future, and this 4 or 8 inches were a part of that several feet, it would be a part of the deepening which

would have an effect upon the piers and breakwaters, wouldn't it?

A. I do not believe that a deepening of 4 or 8 inches should be charged up for any of the cost of any changes in piers or breakwaters for a greater deepening that the Government may do in any of the harbors of the Great Lakes.

Q. And I, of course, understand that you did not take into consideration as an element in your estimate of damage the fact that future commerce may require the extension of existing harbors, or that there may be new harbors necessary.

Mr. Adcock: I object to that "estimate of damage." There is no question of that kind raised or involved here. It is a question of the cost of deepening a certain amount.

Mr. Wilkerson: On what theory is this evidence introduced, except upon the theory that you are trying to show how much you damage the Government if you take the water? I supposed that was admissible for no other purpose except that.

Mr. Adcock: The question assumes a conclusion which is not the case.

Mr. Wilkerson: I am perfectly willing to modify my question.

The Witness: I have estimated for the cost of deepening the channels now in use, the harbors now in use or any isolated docks in use along the Lake Shores and River Shores.

Re-direct Examination by Mr. Adcock.

Q. During the time that Mr. John S. Stevens was Chief Engineer of the Panama Canal, if that is the term you use, was the plan of the canal and the method of construction laid out by him, or under his direction?

A. Yes, sir, and the methods of doing the work and the kind of plant to be used and the organization of the forces necessary for all the department was made and under way, and he is, in my opinion entitled to the credit of making the Panama Canal construction a possibility of success.

Q. He is an engineer of national reputation?

A. He is.

Q. Have you examined the plans of construction of the new lock at the Soo called the Davis Lock?

A. I have.

Q. Is there any such platform provided for as the one that

has been built and in existence at the Poe Lock, that has been mentioned as a breast work 4 inches above the lock floor?

A. A platform is shown on the plans for the Davis Lock, located below the lower mitre gates with its top elevation the same as the elevation of the floor of the lock, the main floor of the lock.

Q. As I understand it, from the time the Poe Lock was built or placed in operation until about 1907, it was not the critical point of navigation in the St. Marys River?

A. I think that is true.

Q. You spoke of the cost of deepening the harbors from 4 to 8 inches and from 8 to 12 inches, and I understood you to say that would cost more in proportion for 8 inches than 4, or 12 than 8?

A. I had in mind the estimate for channels which I had prepared. For the harbors, the estimate was on the yardage basis and for 8 inches would be double of that for 4 inches and for 12 inches three times that of 4 inches, in direct proportion.

The further taking of evidence before the Commissioner in this case is adjourned until such time as may be fixed either by stipulation, or upon the notice of the counsel for the Defendant.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the rooms of the Sanitary District, Chicago, Thursday, September 25th, 1913.

Appearances:
Mr. James H. Wilkerson, and
Mr. Albert L. Hopkins,
Representing the Government;
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian,
Representing the Sanitary District.

HENRY C. ADAMS, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your name, Mr. Adams?
A. Henry C. Adams.
Q. Where do you reside?
A. Ann Arbor.
Q. What is your business?
A. I am Professor of Political Economy and Finance, in the University of Michigan.
Q. How long have you been connected with the University of Michigan in that capacity?
A. As a Professor, since 1887.
Q. And prior to that time?
A. Prior to that time I was a student, and was lecturing in the three universities, Cornell University, Johns Hopkins University, and Michigan. I took the professorship and remained all the year in Michigan in 1887.
Q. Have you been connected with any other institution since that time, or engaged in any other work?
A. I have not been connected with any other institutions, except as now and then I would lecture in other institutions. I have lectured at the Johns Hopkins University off and on for a good many years. And in 1888 I became Statistician to the Interstate Commerce Commission, and held that position until 1907, when I became director, for the Interstate Commerce Commission, of their division of Statistics and Accounts. It was at that time they undertook the development

of a uniform accounting system for the railways of the country.

Q. Did you have anything to do with the development of that accounting system?

A. Yes, sir.

Q. State what you did in that connection.

A. The development of that system was under my immediate direction, and everything was prepared under my direction until it was submitted to the Commission for approval or disapproval, and then promulgated by way of the Commission.

Q. Will you state what your duties were as Statistician to the Interstate Commerce Commission?

A. The usual duties of statistician, having direction of the forms of annual and monthly reports that the railroads submitted; and the direction of all special investigations that the Commission might desire to have made, of a statistical character.

Q. Did you have anything to do with the valuation of railroad property, at any time?

A. Yes, sir, in 1910, I had charge of what is known as the "Determination of the Intangible Values of the Michigan Valuation of Railroads"; and I continued in that advisory capacity to the State of Michigan until after 1905.

Q. Are you about to enter upon any work in connection with the valuation of railroads abroad; if so, state what.

A. Yes, sir, I am going to China as the advisor to the Chinese government on the standardization of Chinese railway accounts.

I might add, also, as bearing upon this point, that in the census of 1890 I had charge of the Department of Transportation, including the Railways, Steam Lines, Express Companies; and I was also employed by the Commission on Railway Mail Pay, of which Senator Wolcott was chairman and made a statistical investigation upon that point for that Commission, which was a Commission composed of both the House and Senate.

Q. Have you made any examination of the records of the City of Chicago as to death rates from various diseases in the last 26 years, say?

A. Yes, sir.

Q. Just state what data you secured, and what has been the nature of your investigation, and the sources from which you secured the information?

A. The information that I studied was secured from the Department of Health of the City of Chicago. That was supported by a study of volumes on Vital Statistics of the Census Office, the Federal Census Office, and by reading excerpts and treaties upon the general subject of health statistics. But the data that I have is supplied by the Department of Health of the City of Chicago.

Q. Is that incorporated in any volume?

A. Not all of it. The volume that I have here, and which was made use of for many of the years covered, is the Report of the Department of Health of the City of Chicago for the years 1907 to 1910. The Department itself furnished me the data covering 1911 and 1912.

Q. Have you made any comparison of the death rates from water-borne diseases between the two periods say 13 years preceding 1900 and 13 years subsequently, as shown by the statistics which you have; and if so, will you state what your conclusions are with reference to that?

Mr. Wilkerson: We are not going to interpose any unnecessarily technical objections to this line of proof. Of course, all this testimony is taken subject to the right to object at the hearing?

Mr. Adcock: Yes.

Mr. Wilkerson: And all that I shall insist on, so far as the figures you use, will be that you indicate to us the document from which they are taken, so that we may have an opportunity to consider either of two things, first: Whether that document is competent evidence; and second, whether the figures are accurate.

Mr. Austrian: For instance, this document that the Professor has described, might not be competent evidence in itself, without calling a witness to identify it.

Mr. Wilkerson: I can conceive of a document of that kind wherein some parts might be competent and some not; some statements might be competent.

Mr. Austrian: We are not going into these statements. All we are using this for is to get figures.

Mr. Wilkerson: I suggest you go ahead with your testimony, and we will reserve the right so far as these documents you use are concerned, to make such objection as we see fit.

Mr. Austrian: That objection is to be made prior to the hearing, and giving us an opportunity to supplement the proof.

Mr. Wilkerson: Even if made at the hearing, you will be given an opportunity to obviate it.

Mr. Austrian: Or qualify it.

Mr. Wilkerson: It may be it will come up before the hearing I think that is the understanding on which this case is to be tried.

Mr. Adcock: Yes.

Mr. Wilkerson: I make that suggestion so that the Professor may go ahead without any interruption, and so that the Government will not be put in the position of waiving any of its rights.

Mr. Adcock: Certainly. I presume Professor Adams can state in the record now the place from which he obtained the data, if he has not already done so.

Mr. Wilkerson: I understood that he got part of it, down to a certain time, from the Report of the Health Department. I understand he has used in this comparison, some figures which he got from some other source. It might be well to indicate from where he got it, where we could find it.

The Witness: They are taken from the records of the Health Office.

Mr. Adcock: Q. Of the City of Chicago?

A. Of the City of Chicago.

Q. Will you state just what those records are, that is perhaps not in detail but in a general way; how they are compiled by the City officials.

A. I am not familiar with the process of compilation by the City officials.

Mr. Austrian: Q. But they are records kept in the office of the City of Chicago Health Department?

A. Yes. And the records are kept in such a way that the tabular statements in this volume are added to from year to year.

Mr. Wilkerson: I suppose they summarize the death certificates, do they not?

Mr. Austrian: That is it.

Mr. Wilkerson: And give the figures as to the number of deaths from different diseases.

Mr. Adcock: The doctor makes a report of the cause of death, and so on.

Mr. Wilkerson: I assume they are statistics compiled from the death certificates.

Mr. Austrian: And the reports are made to the Council, on the proceedings, and in the State courts would be competent without oral proof; might not be in the Federal courts.

Mr. Wilkerson: So far as what they show is concerned,

depends entirely on the statement of the doctors as to the cause of death.

Mr. Adcock: There may be some percentage of error.

Q. Answer the question now.

Have you those documents before you?

A. Yes.

Q. With those before you, kindly state the figures making up the compilations, and the summaries and deductions and conclusions that you make therefrom.

A. The basal statement we find is a statement that shows the death rate per 100,000 population of the City of Chicago for the years 1887 to 1912 inclusive. This statement is divided into periods of 13 years, being 13 years prior to and 13 years subsequent to the opening of the Drainage Canal. This basal statement gives, first, the deaths per 100,000 of population from all causes by years.

Q. That is in the first column?

A. That is in the first column.

Q. The second column gives what?

A. It then gives the deaths from typhoid fever. Third, the deaths from diarrheal diseases. Do you desire these to be mentioned?

Q. Yes.

A. The deaths from tuberculosis, the deaths from pneumonia, the deaths from bronchitis, the deaths from influenza, the deaths from diphtheria and croup, deaths from scarlet fever, deaths from tuberculosis of the lungs, deaths from measles, deaths from whooping cough, deaths from smallpox, deaths from Bright's disease, deaths from heart disease, deaths from cancer, deaths from violence, and deaths from tuberculosis other than pulmonary. And to this is another column added, deaths from all causes in children under five years.

Q. Have you an extra table there of the ones just read?

A. Yes, except that the heads of diseases are not indicated on that second sheet.

Mr. Adcock: Perhaps we had better just offer this in evidence and I will furnish you with a copy of it.

Q. As I understand it, those are tabulations which you have made from the records of the Health Department of the City of Chicago?

A. Yes, sir, they are copies; I could give you the pages of the report they are taken from, if desired.

Q. Of those different diseases which you have mentioned,

what are ordinarily called water-borne diseases and what are air-borne diseases?

Mr. Wilkerson: As bearing upon the competency of this testimony—of course this is a question we will have to argue at the hearing,—I do not know what the purpose of this may be; I do not know what importance may be attached to it at the hearing. If the purpose of this line of testimony is to demonstrate the duty of a city to furnish a pure water supply, the Government concedes that. The Government will concede, claiming, however, if a method is adopted which interferes with navigation, the local authorities can adopt that method only with the concurrence of the Federal authorities. If that is all there is to it, to demonstrate the necessity of a pure water supply, we have no issue.

Mr. Austrian: Will you make the further concession that by adopting this method the City of Chicago has given to its population a pure water supply.

Mr. Adcock: And by the only way it could.

Mr. Wilkerson: We will contend they adopted a method they had no right to adopt, until they had the concurrence of the Federal authority. And we have the evidence in the case, produced by the defendant, which we think amply demonstrates that the water supply could have been purified in a way in which commerce would not be interfered with.

Mr. Austrian: I do not believe you are making any point that those figures are not accurate.

Mr. Wilkerson: I am not making any point one way or another on that, until we have a chance to look them over.

Mr. Austrian: You are not making any objection to the method of introducing these tabulations, instead of introducing the original figures.

Mr. Wilkerson: No, we will check your compilations.

Mr. Adcock: This may be marked "Adams' Exhibit 1."

(Document identified by the witness and offered in evidence was marked Adams Exhibit 1, and here follows:)

ADAMS EXHIBIT ONE.

2—CHICAGO.

Death rates per 100,000 of population.

Years.	All Causes.	Typhoid Fever.	Diarrheal Diseases.	Tuberculosis.	Pneumonia.	Bronchitis.	Influenza.	Diphtheria and Croup.	Scarlet Fever.	Tuberculosis of the Lungs.	Measles.	Whooping Cough.	Small-pox.	Bright's Disease.	Heart Disease.	Cancer.	Violence.	Tuberculosis other than Pulmonary.	Children under 5 years.
1887	2027	50.3	477.6	202.6	132.6	99.2	......	184.9	25.0	180.7	44.9	13.9	.3	42.1	72.2	39.6	126.8	22.0	996
1888	1965	46.7	487.2	201.3	137.7	102.5	......	161.6	22.9	182.1	18.8	22.8	......	41.1	77.1	45.0	110.5	19.2	939
1889	1812	48.4	465.6	181.0	125.0	87.3	0.1	161.4	19.8	164.9	21.8	10.3	.2	39.9	71.0	40.5	104.4	16.0	878
1890	1987	91.6	471.5	201.9	188.5	108.1	10.2	114.7	17.5	182.8	6.1	18.3	......	46.3	74.2	41.9	130.4	19.2	899
1891	2416	173.8	585.3	208.9	251.8	130.1	1.7	118.2	43.4	184.5	23.1	16.9	......	51.7	80.9	47.4	128.8	24.4	1097
1892	2185	124.1	508.6	198.6	199.8	108.6	8.6	129.0	31.8	182.3	15.4	13.7	.2	50.8	88.2	44.9	138.4	16.3	972
1893	2161	53.5	512.6	211.2	196.1	111.4	7.0	117.1	26.3	188.5	18.7	16.8	1.8	60.1	88.3	48.6	151.7	22.7	986
1894	1826	37.5	445.5	191.0	116.1	90.5	3.9	106.4	14.5	167.4	13.9	16.0	78.9	52.0	79.3	48.8	118.4	23.5	842
1895	1772	37.9	372.7	180.2	172.6	82.9	12.1	120.1	5.6	159.1	11.4	8.9	11.5	51.3	99.8	49.9	108.3	21.1	765
1896	1629	52.6	337.2	186.8	150.0	81.6	1.2	76.2	3.8	162.4	5.1	13.1	......	57.3	90.3	51.4	108.7	24.4	680
1897	1463	29.3	278.2	172.6	144.3	68.8	1.0	51.9	5.4	146.4	9.3	10.7	.1	62.8	91.6	49.8	99.7	26.3	574
1898	1464	40.8	241.5	181.7	159.1	63.9	18.0	43.7	4.3	155.2	3.5	13.4	......	67.5	89.8	50.8	97.4	26.5	523
1899	1568	27.2	253.5	178.9	211.4	62.3	19.1	56.4	32.8	154.7	10.3	4.7	.1	72.6	91.7	54.7	97.5	24.2	546
1900	1468	19.8	216.2	173.9	199.5	65.1	9.4	49.5	13.3	153.0	11.4	16.8	.1	65.7	111.4	56.2	97.3	20.8	487
1901	1397	29.1	211.3	164.0	178.5	49.4	11.5	29.4	9.4	142.4	9.0	11.8	.2	57.9	111.1	27.2	99.9	21.6	428
1902	1473	44.5	201.0	165.4	190.6	54.3	6.6	34.8	24.7	141.9	6.8	14.8	.3	69.8	116.5	59.6	104.9	23.5	446
1903	1562	31.8	194.6	182.5	250.1	54.3	9.0	34.4	16.0	155.0	14.9	14.6	2.5	81.9	113.0	57.4	139.9	27.5	447
1904	1410	19.6	177.7	186.5	217.8	44.0	6.0	21.5	7.5	164.8	2.5	5.9	1.5	97.3	107.5	59.2	106.0	21.7	371
1905	1413	16.9	192.5	188.8	184.1	43.5	7.9	22.2	4.1	164.6	11.9	18.4	3.1	103.5	108.3	61.1	108.3	24.2	438
1906	1463	18.5	197.0	192.0	202.5	36.3	6.0	27.7	24.7	161.3	6.4	8.4	......	106.5	109.8	66.5	111.6	30.7	440
1907	1572	18.2	195.4	197.2	232.1	38.4	11.6	27.1	35.1	171.5	12.8	12.0	.05	121.9	113.2	75.1	121.6	25.7	492
1908	1449	15.8	202.3	186.7	167.4	37.6	15.9	26.5	19.6	163.0	8.1	6.4	......	102.0	128.1	74.9	118.1	23.7	459
1909	1458	12.6	171.1	181.0	219.6	6.8	8.7	31.7	17.2	155.9	7.7	6.5	......	105.9	147.4	76.7	126.5	25.1	436
1910	1514	13.7	177.2	178.0	240.8	7.8	6.6	37.4	18.4	153.3	8.7	7.9	.05	113.9	151.4	82.3	116.2	24.7	461
1911	1455	10.9	147.0	166.0	219.6	4.0	5.2	......	......	......	......	......	......	......	......	......	......	......	409
1912	1482	7.5	149.7	163.5	220.4	4.7	2.8	......	......	......	......	......	......	......	......	......	......	......	436

Mr. Adcock: Q. I asked you which of these were commonly known as water-borne diseases and which were impure air diseases?

A. The water-borne diseases are the typhoid fever and the diarrheal diseases, intestinal diseases in general. The impure air diseases are tuberculosis, pneumonia, bronchitis, influenza, grippe, and things of that kind.

Q. What is the difference in the death rate from typhoid fever during the latter period as compared with the earlier period; and by the latter period I mean from 1900 to 1912, and by the former period I mean from 1887 to 1899, both years inclusive, as appears in that compilation.

A. The average death rate per 100,000 population in the period prior to the opening of the Drainage Canal.

Mr. Wilkerson: When was your canal opened?

Mr. Adcock: January, 1899.

Mr. Wilkerson: I object to this on the ground that is not a proper basis of comparison.

The Witness: The average was 62.7. The average for the period subsequent to the opening of the canal was 19.9, showing a reduction in the death rate per 100,000 population of 41.8.

Q. And that is the reduction in the death rate from typhoid fever?

A. Yes.

Q. Between the two periods?

A. Per 100,000.

Q. Per 100,000 of inhabitants?

A. Yes. I might say in the subsequent computations, I used that figure 20 instead of 19.9, just to get rid of the fraction.

Q. And compared the death rate in other diseases, water-borne diseases?

A. With the air-borne diseases.

Q. Before and after the opening of the canal, other water-borne diseases?

A. I should have to furnish that to you. It requires adding. That can be done from the figures here given. I have not worked that out.

Q. Has there been a reduction or an increase in the death rate of water-borne diseases since the opening of the Canal as compared with the period of time which you have mentioned prior to the opening of the Canal?

Mr. Wilkerson: Which particular diseases?

Mr. Adcock: Water-borne diseases.

A. There has been a marked decrease in the death rate in water-borne diseases.

Q. Varying from 25 to as high as 45 per cent., in round figures?

A. Yes, sir.

Q Per 100,000 of population?

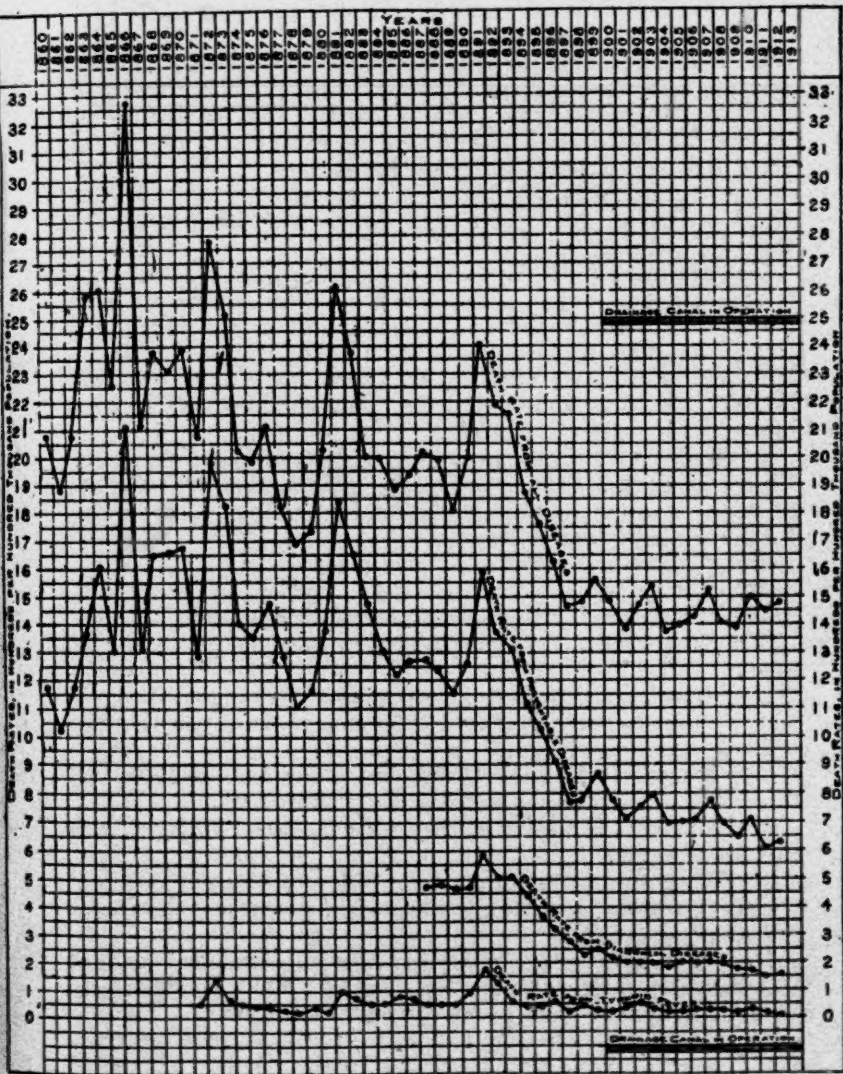
A. And the comparison of that with the air-borne diseases shows that there has been very slight decrease in the air-borne diseases during the same period.

Q. About 6 per cent.?

A. The decrease in the water-borne diseases is 56.9 per cent. and the decrease in the air-borne diseases, computed in the same way, is 6.1 per cent.

Mr. Adcock: I ask that the paper which is presented to the Commissioner be marked "Adams' Exhibit 2."

(Document referred to was marked "Adams' Exhibit 2," and here follows:)



ADAM'S EXHIBIT 2.

Q. Will you explain that exhibit and its compilation?

A. This table presents the death rate in the City of Chicago in a diagrammatic way, the usual curves being adopted; and the table covers from 1860 down to 1912, 1913. The lines represent the death rate from all causes; that is the top line on the diagram. The second line represents the death rate from what is termed "preventable diseases."

The third line is the death rate, the curve from the diarrheal diseases. And the fourth line is the death rate from typhoid fever.

The readings from the table, or the significance of the table is that Chicago, prior to the opening of the Drainage Canal, has always been subject to epidemics. Thus, the curves rise for all diseases to 1866, 1872, 1881, 1891; and fall after the epidemic of 1891; and instead of a recurrence of an epidemic in 1901, the curve shows that the diseases have been brought under some degree of control.

It should be said in explanation of the curve subsequent to 1891, that at that time, shortly after that epidemic, the intake of water was extended in the lakes by putting the cribs out, I believe about four miles.

Mr. Wilkerson: What year was that?

Mr. Austrian: After 1891.

The Witness: It was after that epidemic of 1891.

Mr. Wilkerson: Is this a fact you want to prove in this case?

Mr. Austrian: No, that is so you may not be misled in any way by his answer. In fairness to you, he tells you that the intakes were moved.

The Witness: But the Drainage Canal came in 1901, and since then the curves have been fairly constant.

Mr. Adcock: Q. That is, they have followed straight lines to a large extent?

A. With slight variations they follow a straight line, but the curve for the preventable diseases is constantly declining, dropping, since 1901.

Mr. Wilkerson: Q. What diseases are included in that classification, "Preventable Diseases"? That is, where do we get the figures from which the curve is drawn?

A. I take my authority for answering that question from the Report of the Department of Health, page 109, where the list is as follows: Asiatic cholera, diphtheria and croup, diarrheal disease, measles, pneumonia, bronchitis, puerperal fever, typhoid fever, typhus fever, whooping cough, erysipe-

las, influenza, malarial fever, scarlet fever, smallpox, tuberculosis.

Mr. Adcock: Q. Is there a curve there for typhoid fever? Will you state the conditions of that curve?

A. Yes, there is a curve for typhoid fever in this diagram, but the diagram is drawn to so large a scale that hardly appears as a curve. The figures themselves in the second column of Exhibit 1 will give you a better indication of the movement of the death rate in typhoid fever.

Mr. Adcock: Q. I will have a blueprint made, which the Commissioner can mark, in lieu of the paper that has already been marked as Adams' Exhibit 2.

I ask that the paper which I now hand the Commissioner be marked "Adams' Exhibit 3."

Paper referred to by counsel was marked Adams' Exhibit 3, and here follows:

ADAMS' EXHIBIT 3

6.

COURSE OF THE DEATH RATES
FROM IMPURE WATER DISEASES AND IMPURE AIR DISEASES:
CHICAGO, 1887-1912.

COMPARISON OF TWO THIRTEEN-YEAR PERIODS.
Death-Rates per 100,000 Population.

Year	IMPURE AIR DISEASES (Tuberculosis. Influenza.) (Pneumonia. Bronchitis.) Total	IMPURE WATER DISEASES. Typhoid and Diarrheal Diseases.
1887	434.5	527.6
1888	441.5	533.9
1889	393.4	514.0
1890	508.7	563.1
1891	593.1	758.1
1892	515.6	623.7
1893	525.7	566.1
1894	401.5	483.0
1895	447.8	410.6
1896	419.6	389.8
1897	386.8	307.5
1898	422.7	282.3
1899	471.8	280.7
1900	447.8	236.0
1901	403.4	240.4
1902	416.8	245.5
1903	495.9	226.4
1904	454.3	197.3
1905	424.3	209.4
1906	436.8	215.5
1907	479.4	213.6
1908	407.6	218.1
1909	416.1	183.7
1910	433.2	190.9
1911	394.8	157.9
1912	391.4	157.2

Average Rate.	Impure Air Diseases	Impure Water Diseases
1887–1899	458.7	480.7
1900–1912	430.9	207.1
Decrease	27.8	237.6
Per Cent Decrease	6.1%	56.9%

Q. Will you state what that exhibit is and explain its significance?

A. This Exhibit 3 is a comparison for the two periods already described of the death rate per 100,000 population from impure air diseases and the impure water diseases. The percentage result of that comparison has already been given.

The average decrease in the death rate for impure air diseases is but 27.8 per 100,000 population, whereas, for the impure water diseases, the decrease on a comparison of the average for the two periods, is 237.6, showing a decrease of 6.1 per cent. in the impure air diseases and 56.9 per cent. in the impure water diseases.

Q. Does the death rate from typhoid fever bear any relation to the death rate from other diseases; if so, will you state what the relation is, and what other diseases may be considered in that relation?

A. It is a well established fact, as shown by the statistics of cities before and after the introduction of the improvement of water supply, that the decrease in the death rate of the particular diseases held in mind, and usually this is typhoid fever, is accompanied by a corresponding decrease in the death rate of other diseases. And typhoid fever is commonly accepted as the basis from which to measure the general effects of the improvement of the water supply.

This relationship is what is known as Hazen's Theorem or Hazen's Law. It is universally conceded that the improvement that is reflected in typhoid conditions must be multiplied by some figure in order to get the general improvement in the health conditions of the community.

Q. That is, that the same causes which might effect an improvement in typhoid fever conditions would effect an improvement in other diseases and cause a less death rate in a certain proportion, is that it, a certain ratio?

A. Yes, sir. Here is a statement of Hazen's Theorem as given by himself, he says: "Where one death from typhoid fever has been avoided by the use of pure water, a certain number of deaths, probably two or three, from other causes have been avoided."

Q. Where is that to be found?

A. All my information on this point is taken from an article by W. T. Sedgwick, who is Professor of Biology at the Massachusetts Institute of Technology, and J. Scott McNutt, Health Officer, New Orange, New Jersey, published in the Journal of Infectious Diseases, 1910.

Q. Are they considered recognized authors on that subject?

A. I think Professor Sedgwick is a recognized authority upon this matter in the United States. It was for the purpose of testing the accuracy of Hazen's Law that Sedgwick and McNutt undertook this investigation in American cities.

Q. And how long has Hazen's Theorem, that you have referred to, been recognized as such?

A. I am not sure that I can answer that correctly. My remembrance is that he promulgated this theorem in a paper he read at the time of the St. Louis Exposition, before The International Congress of Learned Societies.

Mr. Wilkerson: Who is Mr. Hazen, what are his initials?

A. He is the Sanitary expert or engineer in New York City.

Mr. Adcock: I ask that the paper I hand the Commissioner be marked "Adams' Exhibit 4."

(Paper referred to by counsel was marked "Adams' Exhibit 4" and here follows:)

ADAMS' EXHIBIT 4

Distribution of Deaths from Typhoid Fever, by sex and age.
Chicago, 1912.

Age	Males	Per Cent of all Deaths of Males	Females	Per Cent of all Deaths of Females	Both Males and Females	Per Cent of all Deaths
1- 5	5	4.27%	4	6.8	9	5.1
5-10	5	4.27	7	11.9	12	6.8
10-20	18	15.4	13	22.0	31	17.6
20-30	42	35.9	20	33.9	62	35.2
30-40	22	18.8	10	16.9	32	18.2
40-50	18	15.4	2	3.4	20	11.4
50-60	5	4.27	1	1.7	6	3.4
60-70	2	1.7	1	1.7	3	1.7
70-80			1	1.7	1	.6
All ages	117	100.0	59	100.0	176	100.0

Males constitute 66.5% of all deaths, females 33.5%.

(Data taken from the records of the Chicago Department of Health.)

Mr. Adcock: Q. Will you explain that exhibit and state what it shows?

A. Which exhibit is that?

Q. Exhibit 4, the Distribution of Deaths from Typhoid Fever, by sex and age?

A. This exhibit shows the distribution of deaths from typhoid fever by sex and by age. The sex classes are under

5, from 5 to 10, from 10 to 20, from 20 to 30, from 30 to 40, from 40 to 50, from 50 to 60, from 60 to 70, from 70 to 80.

The third column of the exhibit shows the percentage of the total diseases borne by males at the various ages named. The significance, or the bearing of the table upon the question of the loss that might be suffered by a city in the absence of proper preventive causes for typhoid fever is that a large percentage of diseases from typhoid fever is suffered by males than females; and that the age when typhoid fever is likely to result fatally for males is between the age, as shown here, between the age of 10 and of 60. Closer figures will show that between the age of 17 and 18 and 55 66-5/10 per cent. of all deaths are male and 33.5 female. The figures here are taken from the records of the Chicago Department of Health.

Q. That is, you mean the figures upon which you base your arithmetical conclusion?

A. The figures that appear in the exhibit.

I would add that the figures in this exhibit influenced me in choosing the multiplier in the application of Hazen's Law.

Mr. Adcock: Q. I ask that the paper which I now hand the Commissioner be marked "Adams' Exhibit 5."

(Document referred to was marked "Adams' Exhibit 5," and here follows:)

ADAMS' EXHIBIT 5.

II.

DECREASE IN VARIOUS DEATH-RATES SINCE THE DRAINAGE CANAL WENT INTO OPERATION.

Comparison of Two Thirteen Year Periods: (1887-1899) and (1900-1912) Death-rates per 100,000 Population.

CAUSE	Decrease in Death-rate (1887-1899) (1900-1912)	Per Cent Decrease (1887-1899) (1900-1912)	Number of Deaths Prevented from cause named for every death Prevented from Typhoid
All Causes....................	398	21.3	9.3
Preventable Diseases.........	418	36.9	9.8
Impure Water Diseases (as recognized by Chicago Dept. of Health)..................	274	56.9	6.4
Impure Water Diseases (as recognized by Sedgwick and MacNutt)..................	‡290	31.8	6.8
Diarrheal Diseases...........	231	55.2	5.4
Typhoid Fever...............	42.7	68.2	....

‡1887-1899 compared with 1900-1912.

Mr. Adcock: Q. Will you explain that exhibit?

A. This exhibit is one designed to show the decrease in the various death rates since the Drainage Canal went into operation; first, from all causes; second, from the Preventable Diseases, and third, from the impure water diseases, as recognized by the Chicago Department of Health. Fourth, from the impure water diseases as recognized in the work of Sedgwick and MacNutt. Fifth, the diarrheal diseases. Sixth, the typhoid fever.

In the last column in that exhibit will be found the ratio between the decrease in the deaths from typhoid fever and the various other diseases.

It is introduced also as having a bearing upon the choice of the multiplier in the application of Hazen's Law to Chicago.

Q. Will you state what territory, and the population, that will necessarily be affected by good health or bad health conditions in Chicago, that is, from an economic standpoint.

A. I recognize in the application of the foregoing facts to Chicago at least three territories with distinct population. The first is the municipality of the City of Chicago. This is the narrowest possible conception of Chicago as a center of population. This is the unit that has bonded itself for part of the investment of the Drainage Canal and I have accepted as the population—part of this of course must be estimated for the last two or three years—present population 2,300,000.

Q. Is that the City of Chicago or the Sanitary District?

A. That is the City of Chicago, the political unit. That is the people here that eat, sleep and work in the city.

The second territory is that which I call the outlying districts; the people who have business in the City of Chicago, but who go out at night to the suburban districts, and for whom health conditions in the City of Chicago are of perhaps as vital importance as to the people who live in the city. There was some difficulty in arriving exactly at the territory to be covered by this second district, but I accepted what is called by the Chicago Association of Commerce, the Manufacturing Zone of Chicago. I have here a map of that zone.

Mr. Adcock: Let it be marked "Adams' Exhibit 6."

(Paper referred to by witness was marked "Adams' Exhibit 6," and here follows:)


Manufacturing Zone of Chicago.
Issued by the
CIVIC-INDUSTRIAL DIVISION
of the
CHICAGO ASSOCIATION OF COMMERCE
LAKE MICHIGAN
LAKE
DUPAGE
Waukegan
Libertyville
Evanston
Elgin
Aurora
Joliet
Blue Island
Harvey
Lockport
Lemont
Wheaton
W. Chicago
Naperville
Palatine
Park Ridge
More than $60,000,000 is being annually expended in industrial enterprises within this manufacturing district.
The death rate of Chicago is lower than any American city having 200,000 or more inhabitants.
Being the center of the food supply of the country, the cost of living is correspondingly low.
No hills to make the transference of freight unusually burdensome.
Unlimited water and electric power at exceptionally low rates.
Longest electric subway freight railway in the world.
Rate of taxation far below the average of American cities.
Sidetrack facilities are easily and economically secured.
The manufacturing zone is large and sites are abundant.
Street car facilities are unequaled by any city of the United States.
Commercial banking resources are larger, in proportion to population, than in any other city of the country.
Best transportation facilities of any city in the world; 40 freight handling railroads, river and canals.
Nearer to every variety of raw material than any other city in the United States.
No extremes of temperature ever cause a temporary suspension of indoor labor.
Annual value of manufactured products, $1,250,000,000.
Center of population of the United States.
Labor abundant and conditions stable.
No floods.

The Witness: (Continuing) This is the territory for which the Chicago Association of Commerce assumes some definite responsibility, and the manufacturing interests within this district are cared for by the association in the same way as the manufacturing interests within the political unit known as Chicago. I have accepted that as evidence of the interdependence of life and commercial interests, their mutuality, in this district.

In the third, there is a large population lying outside even of this district, which is indirectly affected at least because of Chicago's position as a primal market; that is, there is a well recognized territory over which the commercial interests of Chicago have a more or less defined influence. The difficulty arises, of course, in defining strictly this territory, and I have not attempted to do it. For the meat industry, the territory would be defined in one way; for the wheat industry, another; for the jobbing trade, still another; and then for various classes of jobbing and so on. It became so complicated in trying to do that, that I abandoned the attempt; and I may say that I made no use of the population lying in this district, outside of the manufacturing zone of the City of Chicago. But I venture to suggest that any estimate of the loss through the impairment of water supply would be greater than the estimate confined to the municipality or the manufacturing zone, although it is not perhaps capable of absolute measurement.

Q. Professor Adams, have you examined the testimony of Mr. Livingstone, given on behalf of the complainant in this case?

A. Yes, sir.

Q Directing your attention to his estimate of loss to the lake navigation by the opening of the Drainage Canal, and assuming that it is 6 inches in water level loss, have you any comment that you desire to make with reference to his computation?

A. Yes, sir, I have two comments.

Q. Will you make them.

A. In the first place, I doubt if his theory of computing the loss is a satisfactory theory.

Q. By satisfactory you mean a sound theory?

A. A sound theory.

Q. He computed the annual loss at $4,387,500, assuming a depression of the normal lake level of 6 inches. Is that correct?

A. Yes, sir.

Q. Will you state wherein you think his computation or conclusion is inaccurate, and not based upon a sound theory?

A. You have reference now to the theory of the computation?

Q. Of the computation.

A. I understand from the testimony of Mr. Livingstone, that having determined the amount of load that could not be carried because of the level of the water, that he multiplied that loss of load by the rate for carrying the ore—and this is confined to ore—and claimed that that was their loss, without taking into consideration the increased expense incident to that increased freight carried. And I cannot conceive that you could put in a large amount of tonnage into a boat, without increasing in some degree at least the cost of carriage.

Q. What is the second comment.

A. My second comment is that some of the assumptions of Mr. Livingstone, even in applying his theory, are assumptions that do not seem to hold upon an investigation of the transportation on the lakes.

Q. To what do you refer generally, without going into detail?

A. I think I should agree with Mr. Livingstone in confining this loss to ore. I think the analysis of lake traffic will support that proposition.

Q. That is, when you say confining it to ore, deep draught vessels that he refers to in his testimony are ore-carrying vessels?

A. They are ore-carrying vessels, and the conditions of carrying other commodities, with the possible exception of grain—and I should hardly except that—is such that the change in the lake level would not materially affect the situation. But I should disagree with the testimony in the assumption of the average number of trips per vessel. In Mr. Livingstone's estimate, he claimed that every vessel made on an average 20 trips in a season. In Mr. Coulby's testimony, as I remember it, although he did not estimate the loss, he claimed for the Pittsburg Steamship Company 25 trips a season.

Now, my investigation of the trips of the vessels covered by what is known by the "Red Book," the vessels represented by the Lake Carriers Association shows that the average number of trips for all those vessels is but 11.6.

Q. And from what source did you obtain the statistics upon which you arrived at the figures 11.6?

A. Before answering that might I add, so as not to be confused, that in the Pittsburg Steamship Company it is higher, and also in quite a number of the fleets other than the Pittsburg Steamship Company the average would be higher than 11.6.

Q. But that is the entire average of all vessels included in the "Red Book"?

A. Yes.

Q. The Red Book constituting all vessels belonging to the Lake Carriers Association the average is 11.6?

A. Yes.

Q. Do the records show the average number of trips of each vessel; that is, you have calculated the average number of trips from the records at the Soo. Is that correct, Professor?

A. Yes, sir, I took an account of every boat that went through the St. Mary's Canal for the year 1912.

Mr. Wilkerson: Q. Without regard to whether its draught was so large it would be affected by this change of 6 inches, or not?

A. I excluded from the compilation, in order to arrive at the averages that I have stated, such things as towboats and lighters and all that class of boats. The boats covered by the averages stated are boats carrying freight.

Mr. Austrian: And are the same boats included in the list of boats upon which Mr. Livingstone arrived at his figure of 20 average trips.

Mr. Wilkerson: It may be or may not.

Mr. Adcock: Q. Mr. Adams, there was a federal statute passed February 21, 1891, which required the compilation of this data, was there not?

A. Yes, sir.

Q. And a form prepared by the federal department for the purpose of recording and making note of the data?

A. Yes, sir.

Q. You have one of those forms here present, or several of them?

A. Yes, I have one for the up trips and one for the down trips.

Q. Those are the two documents which I now show you, are they not?

A. Yes, sir.

Mr. Adcock: We will offer these in evidence as Adams' Exhibit 7 and 8.

(Papers identified by the witness were marked Adams' Exhibit 7 and 8, and here follow:)

E31(a)

ADAMS' EXHIBIT 7.

(Public—No. 92.)

An act to facilitate the collection of commercial statistics required by section 2 of the river and harbor appropriation acts of eighteen hundred and sixty-six and eighteen hundred and sixty-seven.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That owners, agents, masters and clerks of vessels arriving and departing from localities where works of river and harbor improvement are carried on shall furnish, on application of the persons in local charge of the works, a comprehensive statement of vessels, passengers, freight and tonnage.

Sec. 2. That every person or persons offending against the provisions of this act shall, for each and every offense, be liable to a fine of one hundred dollars, or imprisonment not exceeding two months, to be enforced in any district court in the United States within whose territorial jurisdiction such offense may have been committed.

Approved February 21st, 1891.

Trip No. ________

Statement of Traffic
Passing Through
St. Mary's Falls Canal

________190____

From ________ ________
To ________ ________

Bound Down
(East)

Name and Class of Vessel ________
Draft of Water ________ feet ________ inches
Copper, tons ________
Grain, bushels (Corn, Oats, Rye, Barley, Flax Seed) ________
____
Building Stone, tons ________
Flour bbls. ________
Iron Ore, tons ________

Iron, Pigs, tons ____________________

Lumber, M ft. ____________________

Silver Ore, tons ____________________

Wheat, bushels ____________________

Unclassified Freight, tons ____________________

Total Cargo, tons ____________________

Passengers, number ____________________

____

Clerk Master

N. B.—(All tons are "net" tons of 2,000 pounds except where otherwise specified.) Detroit March, 1905—30,000.

E31(b)

ADAMS' EXHIBIT 8.

(Public—No. 92.)

An act to facilitate the collection of commercial statistics required by section 2 of the river and harbor appropriation acts of eighteen hundred and sixty-six and eighteen hundred and sixty-seven.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That owners, agents, masters and clerks of vessels arriving and departing from localities where works of river and harbor improvement are carried on shall furnish, on application of the persons in local charge of the works, a comprehensive statement of vessels, passengers, freight and tonnage.

Sec. 2. That every person or persons offending against the provisions of this act shall, for each and every offense, be liable to a fine of one hundred dollars, or imprisonment not exceeding two months, to be enforced in any district court in the United States within whose territorial jurisdiction such offense may have been committed.

Approved February 21st, 1891.

Trip No. ______________

Statement of Traffic
Passing Through
St. Mary's Falls Canal

______________________191___

From ______________________ ______________

To ______________________ ______________

Bound Up
(West)

Name and Class of Vessel ______________________

Draft of Water ______________ feet ______________ inches

Coal, tons Soft ______________ Hard______________

Grain, bushels (Corn, Oats, Seeds, Cut Feed)______________

Flour, bbls.______________________

Manufactured Iron, tons______________________

Salt, bbls. ______________________

Unclassified Freight, tons ______________________

Total Cargo, tons ______________________

Passengers, number ______________________

____

Clerk Master

N. B.—All tons are "net" tons of 2,000 pounds, except where otherwise specified.

Detroit, April 12, 20,000.

Mr. Adcock: Q. And those documents when made out are recorded and filed at the Soo?

A. Yes.

Q. And it was those documents which you examined?

A. Yes, sir.

Q. And those are the documents which you referred to as having been the documents from which you made the compilation, additions, deductions and averages concerning which you have just testified?

A. That is true.

Q. You had finished that answer of yours, had you not, Professor?

A. No, sir. There is one point I should like to state as modifying somewhat my previous statement that the average was 11.6, the average number of trips. I separated these trips and vessels according as the report of the captain relative to draughts was less than 18 feet 10 or above 18 feet 10. If we confine the statement of the average trips to the boats which drew, on their down trip, those are the trips carrying

ore, 18 feet 10 or above, the average number of down trips for all vessels of this class is 14.12.

Q. That is, if you separate them?

A. And that is the figure which it seems to me should be placed in comparison with the assumption of Mr. Livingstone that the average number of trips per vessel is 20.

Q. What further comment, if any, have you to make upon Mr. Livingstone's method of ascertaining the loss?

A. Mr. Livingstone claims, as I understand him, that the Lake Carriers' Association, for which he speaks, covers about 7/8 of the vessels that would be affected by the reduction of the level, and adds, therefore, to his computation 1/8 for other vessels not in his Association.

Now, I do not find from the records of vessels passing through the St. Mary's Canal that there were more than 12 vessels carrying ore, and but six loads of wheat over 18 feet 10. Therefore it seems to me that ought not to be added, with this possible exception, that my figures do not take into consideration the transportation from port to port below St. Mary's Canal, as for example ore from Escanaba; but that is a relatively small amount.

Q. Professor, have you examined the testimony of Mr. Sadler, bearing upon this point?

A. Yes, sir.

Q. Do you concur in the view that he adopted?

A. I think the principle underlying his estimate is correct.

Q. State what that principle is?

A. That principle is that in estimating the loss due to decreased freight—

Q. Decreased carrying capacity?

A. Decreased carrying capacity, you must take into consideration operating expenses as well as the revenue. That is, if for any reason you increase the amount of freight carried, the gain is only the net gain, and not the gross gain.

Q. Professor, do any class of vessels benefit by the fact that these so-called deep draught boats do not carry at times, as they claim, full capacity?

A. I think so, yes, sir.

Q. What do you base that conclusion on?

A. I base that conclusion upon a comparative study of the various fleets, upon the fact that there seems to be classes of carrying capacity on the Great Lakes, and that there are

certain fleets that when things are slack take the freight and leave the other boats to do nothing.

Q. What class of vessels do you refer to?

A. Especially the Pittsburg Steamship Company's vessels.

Q. Do you know by whom they are owned?

A. They are owned by the Steel Corporation.

Mr. Wilkerson: Do you know that? I move to strike out the answer.

Mr. Adcock: Q. Upon what do you base that statement?

A. I base that statement on the report of the Commissioner of Corporations, on the Steel Industry; that being a Report issued under the authority of the Department of Commerce and Labor.

Q. What volume is it?

A. I don't know; I have got both volumes here.

Mr. Wilkerson: With great respect for the Government Reports, I still insist on my motion, because you cannot prove that fact even that way. I would not object if it had the slightest bearing upon any possible issue in this case. It has not the slightest bearing on any question involved in this case. There is no use putting it in the record.

Mr. Adcock: Inasmuch as the Government counsel has raised the question as to the competency of your testimony, I draw your attention to the testimony of Mr. Coulby, who is the President of the Pittsburg Steamship Company, to be found upon page 721 of the record in this case, in which he says that the "Pittsburg Steamship Company is a corporation organized under the laws of, I think the State of West Virginia. The United States Steel Corporation owns the stock." That was one of the elements that you took in consideration in arriving at your answer that it was owned by the Steel Corporation, is that correct?

Mr. Wilkerson: If the fact is proven in the record by competent evidence, what is the use of having somebody swear to it who is incompetent.

Mr. Adcock: Q. Professor, from a scientific view point, is there any method which you can adopt for the purpose of ascertaining the saving to a community annually by the reduction in the death rate and maintenance of the health of those constituting that community?

A. Yes, sir.

Q. Have you computed the saving to this community, and by this community I mean the community to which you have heretofore referred, by the reduction of the death rate and

diminished illness due, as you have testified, to the betterment of conditions surrounding the water in this Sanitary District?

Mr. Wilkerson: In addition to the general objection which we urge against that, we urge the specific objection that the matters embraced within the scope of that question are beyond the scope of that which the witness has qualified himself to speak with reference to, as an expert witness. It embraces elements that must necessarily be taken into consideration, that are outside the subject which he has stated he is competent to testify in regard to.

Q. (Last question read.)

A. Yes, sir.

Q. Is that a statistical question, or a question for a statistician or political economist, or a combination of both?

A. It seems to me to rest entirely upon statistical rules and principles, and upon ecomonic analysis.

Q. And are you familiar with those?

A. Yes, sir.

Q. Have you devoted years of study to them, taught them, lectured upon them, read upon them?

A. Yes, sir.

Q. Have you computed what that saving to this community is, Professor?

A. Yes, sir.

Q. Annually, I mean?

A. I computed the annual saving.

Q. Will you state how much that is?

Mr. Wilkerson: Are we to have the benefit of his methods?

Mr. Adcock: You can cross examine.

Mr. Wilkerson: Then I object to the question as incompetent, irrelevant and immaterial, and as calling for an improper conclusion of the witness.

A. I have expressed the figures that I have here in the language of loss rather than gain. But what I have to say is—

Q. Answer it in your own way.

A. As I have computed the loss that would be sustained by the City of Chicago and dependent population, were the present facilities for obtaining an adequate supply of pure water impaired or destroyed, based upon a comparative study of health statistics of the City for thirteen years before and thirteen years after the opening of the Chicago Drainage Canal, for the City of Chicago as a municipality.

Q. Upon the theory that it was 2,300,000 inhabitants, I take it?

A. Upon the assumption it has 2,300,000 inhabitants I computed it to be $17,899,000 a year.

Q. And on the theory that it had 2,100,000 inhabitants?

A. It would be proportional.

Q. The same proportion?

A. That is, this analysis is first made per 100,000 of population as a unit, and then for any population for any district, if can be computed.

Q. Will you give us the unit figure on 100,000?

A. The unit figure on 100,000 is $778,246. Now the Sanitary District, having a population larger than the City of Chicago will suffer an annual loss of $19,237,000. That is upon the assumption of a population of 2,472,000 for the Sanitary District.

Q. But whatever the population is, it would be a multiple of the unit you have given of 778,000 and some odd hundred dollars?

A. Yes, sir.

Q. This increased cost that Mr. Livingstone spoke of to the Pittsburg Steamship Company by reason of the claim of the lowering of the lake levels by the opening of the Sanitary District Canal, have you made any investigations for the purpose of ascertaining whether if that increased cost were removed, the consumer of the steel products would obtain the benefit thereof?

A. Yes, sir.

Q. What investigations, if any, have you made?

A. I have studied the position of the United States Steel Corporation in the general conditions for the manufacturing of steel products, and come to the conclusion that they held rather a dominating influence; and further have compared the courses of prices of steel products before the organization of the Steel Corporation and after the organization of the Steel Corporation, and find that in my judgment they have been pretty steady, or that they have not been subject to competitive influences, and that the prices have not been reduced to the consumer.

Mr. Wilkerson: I move to strike out the conclusion and finding of the witness for every reason that can possibly be assigned as objection to an answer. I know of no rule that is not violated by that answer.

Mr. Adcock: Q. Have you any diagrams or data which

have been prepared which will show the prices before and after the organization of the Steel Corporation?

Mr. Wilkerson: I object to this entire line of testimony, not only as incompetent, but also as to the manner in which it is attempted to prove these facts.

A. The diagrams that I have are taken from the transcript of the record in the District Court of the United States for the District of New Jersey, United States of America vs. The United States Steel Corporation and others.

Q. And those appear in the testimony of Mr. Walker who made those—

A. Who was the Government's witness in this case, and Mr. Walker is the—

Q. Is the statistician who prepared those charts?

A. I think he is the deputy commissioner of corporations at the present time, of the Bureau of Corporations.

Q. Will you refer to the different charts there which you have in mind, and the page of the record on which they appear?

A. Yes, sir.

Q. And state what those charts and diagrams show?

A. The first chart that I selected was chart numbered 1652 in the record. It shows the average monthly prices of Bessemer pig iron and Bessemer billets at Pittsburg, and heavy Bessemer rails at mills in Pennsylvania. It is a chart made upon the tables appearing in this record, 5, 6 and 7.

Q. And it is Walker Government Exhibit No. 245, date November 19, 1912?

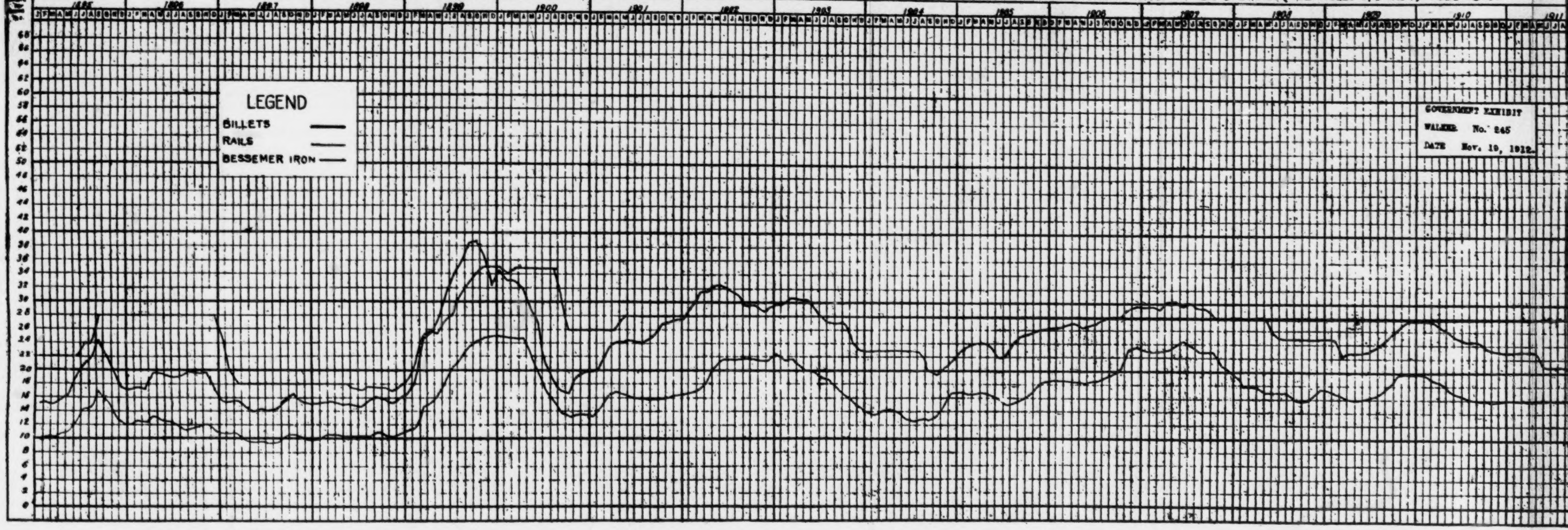
A. Yes.

Mr. Adcock: This will be Adams Exhibit No. 9 in this case.

(Document identified by the witness is marked Adams Exhibit No. 9 and here follows:)

DIAGRAM III

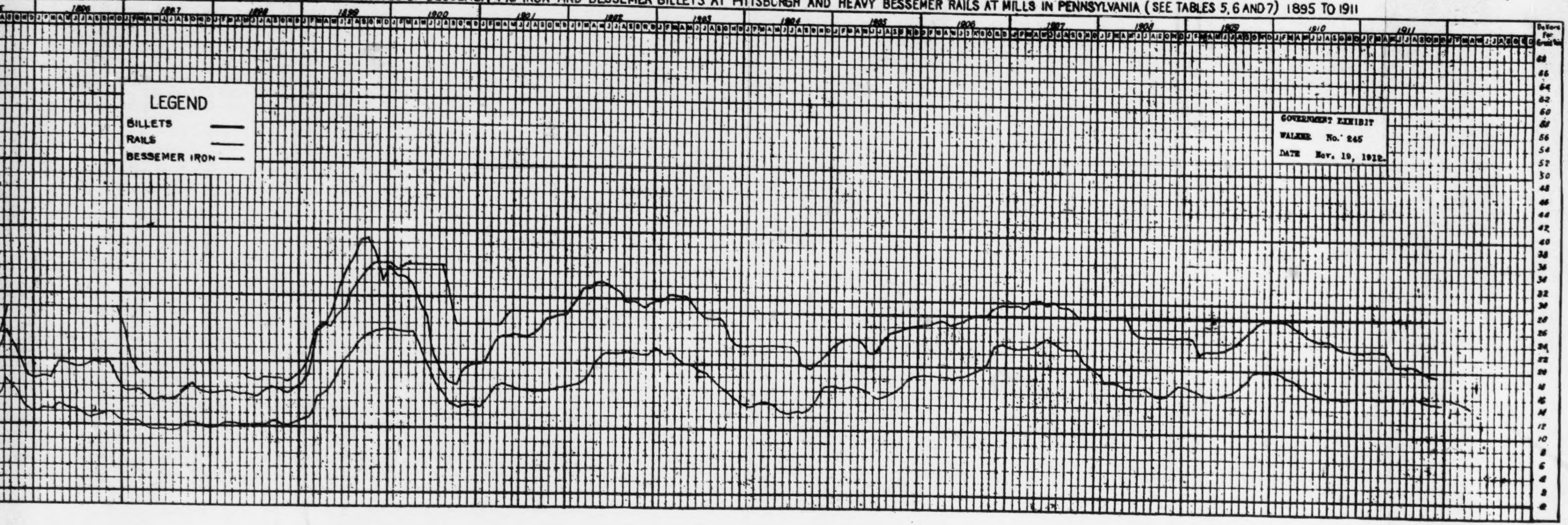
AVERAGE MONTHLY PRICES OF BESSEMER PIG IRON AND BESSEMER BILLETS AT PITTSBURGH AND HEAVY BESSEMER RAILS AT MILLS IN PENNSYLVANIA (SEE TABLES 5, 6 AND 7) 1895 TO 1911



III

AVERAGE MONTHLY PRICES OF BESSEMER PIG IRON AND BESSEMER BILLETS AT PITTSBURGH AND HEAVY BESSEMER RAILS AT MILLS IN PENNSYLVANIA (SEE TABLES 5, 6 AND 7) 1895 TO 1911

Adams' Exhibit 9



Mr. Wilkerson: This is all subject to objection, exhibit and all.

Mr. Austrian: I understand if the evidence is material, that you do not object on the ground we are introducing it without producing Mr. Walker.

Mr. Adcock: If you want us to produce Mr. Walker—

Mr. Wilkerson: No, I am perfectly willing that the chart may be treated as if Mr. Walker said here what he said in that case about having made it. I do not insist on your bringing him here; but I insist that from any standpoint it has no bearing whatever upon any issue presented in this case. It is perfectly inconceivable that the question of interference with navigation should be even remotely connected with the increase in the price of steel.

Mr. Austrian: The reason why we are offering this testimony, and I state it in the record, is because in the Government's case they undertook to prove that by reason of the alleged lowering of lake levels the cost to the consumer of the product so carried was increased; and the main product referred to was ore and steel.

The Witness: This diagram shows that for steel rails the curve is a straight line from March, 1901.

Mr. Adcock: Q. Up to and including 1912?

A. Up to and including December, 1911.

Q. That is, they were $28 a ton?

A. The rails were $28 a ton.

Q. Every day and every month in the year of each year?

A. Yes, sir; that the other commodities named fluctuated, but they do not fluctuate as violently as they did prior to 1901, the date of the organization of the Steel Corporation.

Q. Will you indicate in the record what those fluctuations disclose as to higher or lower cost of the products referred to?

A. The diagram indicates that the fluctuation in billets and Bessemer iron was subject to about the same influences, whatever those influences may be; but that in neither case is the fluctuation as violent as prior to the formation of the Steel Trust, and they are on the average above the level prior to the formation of the Steel Trust.

The Table No. 1675—

Mr. Adcock: Appearing at page 1675 and being Government's Exhibit Walker No. 268, date November 20, 1912, in the case referred to.

A. That gives the price of steel rails in the United States and in England from 1895 down to and through 1911.

Mr. Adcock: That may be treated as Adams Exhibit No. 10. I will substitute a copy.

Mr. Austrain: Under the same stipulation.

Mr. Wilkerson: Yes.

(Table identified by the witness was marked Adams Exhibit 10, and here follows:)

ADAMS' EXHIBIT 10.

1675
Government Exhibit Walker No. 268
Date, Nov. 20, 1912

TABLE 52. Average Price of Heavy Steel Rails in England and in the United States, 1895 to 1911, by months (Dollars per Gross Ton).

	1895		1896		1897		1898		1899		1900	
	England	United States	England	United States	England	United States	England	United States	England	United States	England	United States
January.....	17.18	22.00	23.11	28.00	22.38	25.00	21.90	18.00	22.96	18.50	34.06	35.00
February...	17.03	22.00	23.11	28.00	22.50	20.00	21.90	18.00	23.11	20.25	34.37	34.20
March......	17.27	22.00	23.11	28.00	22.05	18.00	21.90	18.00	23.23	24.80	36.01	35.00
April.......	17.64	22.00	22.50	28.00	21.90	18.00	21.90	18.00	24.48	25.75	37.40	35.00
May........	17.64	22.00	22.14	28.00	21.90	18.00	21.90	18.00	24.94	25.20	37.71	35.00
June........	17.64	22.00	21.90	28.00	21.90	18.00	21.90	17.50	25.30	27.25	37.10	35.00
July........	17.64	24.00	21.90	28.00	21.90	18.00	22.14	17.00	30.26	28.25	36.50	35.00
August.....	18.25	24.00	21.90	28.00	21.90	18.00	22.50	17.50	30.41	31.00	35.16	35.00
September..	19.31	28.00	21.90	28.00	21.90	18.00	22.50	17.50	32.36	32.50	34.06	30.25
October....	21.13	28.00	21.90	28.00	21.90	18.00	22.50	17.50	32.85	34.00	34.06	26.00
November..	22.87	28.00	21.90	28.00	21.90	18.00	22.50	17.50	33.76	35.00	30.66	26.00
December...	23.11	28.00	21.90	28.00	21.90	18.00	22.50	17.50	34.06	35.00	28.89	26.00
Average..	18.89	24.33	22.27	28.00	22.00	18.75	22.17	17.63	28.14	28.13	34.67	32.29

	1901		1902		1903		1904		1905		1906	
	England	United States	England	United States	England	United States	England	United States	England	United States	England	United States
January.....	28.59	26.00	26.28	28.00	26.76	28.00	22.87	28.00	21.90	28.00	29.35	28.00
February...	27.67	26.00	24.63	28.00	26.76	28.00	21.90	28.00	23.72	28.00	30.11	28.00
March......	25.79	26.00	25.70	28.00	26.76	28.00	21.90	28.00	24.45	28.00	30.41	28.00
April.......	25.55	26.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	30.41	28.00
May........	25.06	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	30.87	28.00
June........	25.24	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	31.02	28.00
July........	26.76	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	31.02	28.00
August.....	26.76	28.00	26.76	28.00	25.55	28.00	21.90	28.00	25.55	28.00	31.02	28.00
September..	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	25.55	28.00	30.72	28.00
October....	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	25.55	28.00	30.41	28.00
November..	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	28.13	28.00	30.53	28.00
December...	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	28.95	28.00	31.63	28.00
Average..	26.54	27.33	26.45	28.00	25.85	28.00	21.98	28.00	25.50	28.00	30.63	28.00

	1907		1908		1909		1910		1911	
	England	United States	England	United States	England	United States	England	United States	England	United States
January.....	32.08	28.00	29.80	28.00	26.15	28.00	25.55	28.00	27.52	28.00
February...	32.69	28.00	29.20	28.00	25.55	28.00	26.00	28.00	27.98	28.00
March......	32.85	28.00	29.20	28.00	25.55	28.00	26.15	28.00	27.86	28.00
April.......	32.85	28.00	28.59	28.00	25.55	28.00	26.28	28.00	27.37	28.00
May........	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
June........	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
July........	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
August.....	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
September..	32.08	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
October....	31.63	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
November..	30.66	28.00	27.67	28.00	25.55	28.00	26.76	28.00	27.37	28.00
December...	30.41	28.00	26.76	28.00	25.55	28.00	26.76	28.00	27.37	28.00
Average..	32.22	28.00	28.26	28.00	25.60	28.00	26.51	28.00	27.47	28.00

The Witness: This exhibit in generel indicates where there has been a perfectly uniform price for steel rails subsequent to the organization of the Steel Corporation, that the price of steel rails in England has been subject to fluctuations; part of the time the price in this country being above and part of the time below in England.

On page 1657, there is a diagram being Walker Exhibit No. 250, date November 19, 1912, which shows a simple average price of steel products from 1895 to 1911, inclusive. These products are light steel bars, light steel, steel bars, black sheets, A wire, and wire nails covered by one line; and heavy steel billets, standard rails, beams and plates by the other.

Q. The former being a black line and the latter a red line?

A. The latter a red line, yes, sir. This table shows the same general trend of prices as before, the extreme fluctuations prior to the formation of the Steel Corporation, and relatively steady prices subsequent to that time, and prices that for considerable periods do not vary greatly.

Mr. Adcock: That last table will be marked Adams Exhibit 11.

(Table Walker Exhibit 250, was marked Adams Exhibit 11 and here follows):

DIAGRAM VIII

The Witness: I refer next to page 1656 being Walker Exhibit 249, date November 19, 1912, which is a diagram showing the simple average price of Bessemer pig iron, foundry pig iron, Bessemer billets, steel rails, beams, tank plates, steel bars, black sheets, plain smooth wire and wire nails, from January 1895 to December, 1911, inclusive.

The line representing the averages here shows the same general trend as the other tables, but this diagram gives an average price for all these commodities for the years January 1st, 1895, to March 31, 1901, and compared with it an average price from April 1st, 1901, to February 8th, 1909; the latter being higher than the former.

This diagram also shows the basis upon which these quotations rest, being taken from the Iron Age, except for standard rails which are taken from the reports of the American Iron & Steel Association. And with regard to the authority for these prices, that will be found fully described in the testimony by Mr. Walker, which is in volume 7 of the same report.

(Table Walker Exhibit No. 249, was marked Adams Exhibit 12, and here follows):

Mr. Wilkerson: I want to say about this whole line of testimony that I propose to move the court before we close our testimony in rebuttal, to strike all this evidence from the record, on the ground it has no bearing on this case whatsoever. I am at a little disadvantage in connection with the completion of the cross examination of this witness on these points. He has gone into an issue here which is in controversy in the other lawsuit which involves, as I understand it, the question whether there was a combination to control the price of steel, a matter in litigation in the federal courts. And if the court should hold this would have any possible bearing on this case, I would have to pick out offhand what other portions of the record I want to direct the attention of the witness to.

Mr. Austrain: We are not introducing any testimony given in another case. We are simply taking charts that were prepared showing the prices, over which there can be no dispute, prepared by the Government's own expert witness, as to steel and ore products.

Mr. Wilkerson: You are using them as a foundation for certain conclusions that you ask this witness to draw. It may be there are other things which ought to be directed to his attention.

Mr. Austrain: He is not drawing any conclusion except from these diagrams.

Mr. Wilkerson: Go ahead.

Mr. Austrain: He takes the exhibits prepared by your own Government expert as correct. If they are not correct, that is easily ascertained, because it is a matter of public record.

Mr. Adcock: That is all.

Cross Examination by Mr. Wilkerson.

Q. Professor, you gave some figures here which you stated represented in your opinion, the loss which would have resulted if the death rate during the period of 15 years prior to the opening of the Canal for typhoid fever had remained the same during the 13 years following the opening of the Canal, as I understand you?

A. Yes, sir.

Q. In that, you assumed that there would have been more people who would have died during the second period than the first?

A. If it had not been for the improvement in the sanitary conditions, yes, sir.

Q. And that none of those might not have died from other causes?

A. That is the assumption, because the comparison is made with the expectation of life, including all diseases.

Q. And you have undertaken to give your opinion in dollars and cents of the loss which would have resulted to the community if a certain number of people had died and had become sick. Is that what you attempted to do?

A. Yes, sir.

Q. You have presented a table here in which wou have shown the death rate per 100,000 in the City of Chicago during the years running from 1897 to 1912. Have you had occasion to make any study of the death rate of any other American cities during the same period?

A. Not as careful a study as that of Chicago; but I have always been interested in that study and have made something of a comparison between the result here and other cities.

Q. I mean, in connection with this specific investigation?

A. Yes.

Q. You have limited yourself to the City of Chicago?

A. Yes, in that case I have.

Q. Have you given any consideratior to the change of death rate throughout the entire nation?

A. Yes, sir, except the statistics don't exist for the entire nation. It is not possible to go beyond, in that study, what is called the registration districts, which covers the states that have laws regarding uniform registration of death and illness.

Q. Have you given any consideration to the diminution, the comparative diminution of the death rate in cities where during a particular period there has been a large movement into the city of persons between certain ages, say between 20 and 40 years old, and as to whether or not that would tend very materially to diminish the death rate?

A. I have not asked whether the increase of population through immigration was greater or less in Chicago as compared with other cities.

Q. Have you in the conclusions which you have drawn with reference to the diminution of the death rate in Chicago given any consideration whatever to the immigration during the respective years into the City of Chicago, and to the ages of the immigrant?

A. No, I have not.

Q. Are you aware of the fact that in small towns and

cities, where there is no immigration of adult persons of an age where the death rate is comparatively low, in small towns and cities the death rate appears to be high compared with other towns and cities into which there is that immigration?

A. I do not know that is so.

Q. You have never given it any consideration?

A. I do not know that that is true.

Q. It would naturally have a very great effect upon the death rate, would it not, if you bring into a community each year a large percentage of immigrants between the age of 20 and 40 years?

A. I think you ought to have a medical expert to answer the question, but my impression is that outside of the tubercular diseases, the germs do not live long enough, so that it is the local condition rather than the condition of the immigrant that effects the death rate.

Q. My point is this: If you have a thousand persons between the age of 20 and 40 years, there would be fewer of that thousand die than of a thousand whose age is over 50, would there not?

A. Yes, but not of typhoid fever.

Q. No, I am speaking of the whole death rate, the total death rate.

A. Of the total death rate, it is a universal truth that the older the age of the group the less expectation of life will that group have. If you mean that, yes.

Q. And the same thing is true with reference to young people; that is, the death rate is very high in young children?

A. Yes, in certain diseases.

Q. So that if you reduce in the community the percentage of small children and of old people, you will have a lower death, would you not?

A. Yes.

Mr. Austrian: Other things being equal.

Mr. Wilkerson: Other things being equal.

Q. Now, I notice in this table that you have presented that, take the year 1897, for instance, which was before the opening of the Canal, the death rate per 100,000 from typhoid fever was 29.3, while in 1902, which was three years after the opening of the Canal, the death rate from the same source was 44.5 per 100,000. You noticed that fact, did you?

A. Yes, sir.

Q. Which would indicate, would it not, that the prevalence of typhoid fever, while it might have been to some ex-

tent influenced by the opening of the Drainage Canal, was determined by other factors than that alone?

A. I can't answer that "Yes" because that brings in yet another point, on which you ought to have a medical expert; but I can tell you what the medical expert would say upon that, because I have asked him and he has told me.

Mr. Wilkerson: I have no objection to the Professor giving us any light he can.

The Witness: My understanding about this is bound up with these epidemic years. I first got this explanation from Dr. Young, who is your health officer here in Chicago; and also from talking with physicians who are expert in this matter. That is all I know about it. And from these conversations I understand it to be the opinion of the medical experts that naturally, other things remaining the same, any congested community will have epidemics about once in ten years; that the fact of an epidemic itself is a sort of vaccination against the recurrence of these diseases; and this figure here, 29 and 44 are the years when had there not been a control you would have had an epidemic here in Chicago.

Q. So that this high average for the period before the opening of the Canal grows out of the fact that included in that period are two or three years in which there was an epidemic of typhoid fever in Chicago?

A. Yes.

Q. That is, 1890, 1891, 1892. We are all familiar with that period.

A. And of course might I add this: That as a statistician I should dislike to undertake to explain one year against another year. It is always necessary to cover a sufficiently broad basis of figures, and data over a sufficiently extended period, so that these local factors are eliminated.

Q. Why was it necessary to take a period of 13 years? Why was it necessary to go back far enough to include that epidemic period?

Mr. Austrian: That is because it is 13 years since the opening of the Canal.

The Witness: If it had been five years from this time, I should have gone 18 years instead of 13. Thirteen is all the years we have since the opening of the Canal.

Mr. Wilkerson: With reference to the statements of the witness as to opinions concerning loss which would have accrued to the City of Chicago had the death rate during the one period to which he has referred remained the same dur-

ing the second period covered, I move to strike out each and every statement of the witness on that subject, on the ground that it is the mere expression of an imaginary opinion; that there is no statement in the evidence of the alleged loss or damage; no basis whatsoever for determining the principle upon which the conclusion of the witness is based. That is all.

Mr. Austrian: The witness is here, and if the Government's attorney wants to know how he arrived at the computation, what elements entered into it, he is here ready to be cross-examined.

Mr. Wilkerson: If the counsel for the defendant do not see fit to bring out in the record the elements of the alleged loss or damage, I do not conceive it is part of the duty of the counsel for the Government to bring out evidence on that subject.

Re-direct Examination by Mr. Austrian.

Q. So that there may be no quibble about it, or question about it, we will ask the witness as a part of our direct examination to state to the Government attorney what elements entered into that computation; not recognizing however the correctness of the rule that he lays down. We do not desire to speculate with so important an element in this case.

A. You ask for the methods followed in computing the loss to which I testified?

Q. Yes.

Mr. Wilkerson: I think what you wanted more particularly was a statement of the elements of the loss.

Mr. Austrian: Yes, the methods that he employed in arriving at the loss and the reasons; and how he reached the figures testified to.

The Witness: The factors employed in computing the community loss on account of premature death as working citizens are, first: the number of working years annihilated by premature death. For any given person this is measured by the difference between the age at which death occurs and the normal expectation of life for that age. For the community, the average at which death occurs is the point from which the measurement is taken.

The second factor is the worth or value to be imputed to a working year. By the first, it is evident that we learn the number of working years for each year annihilated by a premature death. If now we know the value to the community

of a working year, the multiplication of the one into the other gives the desired result.

Q. You arrived at the value for a working year?

A. Yes, sir, but might it not be well to state how the other is arrived at first. That is well established by actuarial methods. And in the case of typhoid fever, which is made the basis of this computation, the loss, the average age of those who died of typhoid fever is 29 and a fraction years. Now, the average expectation of life for that age, 29, is 66 years. If now we take 65 as the limit of working years, there is by a death of typhoid fever annihilated the difference. At that age there is an expectation of 36 working years for each person that dies. Therefore, the deaths multiplied by 36 years gives the loss to the community in years.

Now, the other element the value of a year is one that the actuaries have always dodged. They have made assumptions, but have never given the matter, in my judgment at least, sufficient analysis, industrial or economic analysis.

I have for the purpose of this case endeavored to analyze the community's interest in premature deaths. And by the community's interest I mean the interest of the community as though the community were a unit, an organization, an industrial corporation, you may say, of perpetual life. And starting from that point, the burden that must be placed upon current industry is the burden first of maintaining the current social asset, the important asset being in the number of workers in existence, so that notwithstanding deaths there will be births, raising children, education of workers, who will come to supply the place of the worker so that what you may call the labor asset of the community will be maintained.

Every time there is a premature death, the community loses in this respect; that is, the fund for the maintenance of its industrial or social aspects is impaired.

It is also a burden or a duty imposed upon current industry to provide for the normal development of industry, the normal growth of society, increase in numbers and increase in grade, quality of labor, greater education; and that I call as distinguished from maintenance of development, the additions and betterments that come to this society, considered as an industrial organization. Those are the two elements that are attempted to be measured; and each of them is impaired by a premature death.

Then, third, there is a dissipation of assets, a dissipation of energy, dissipation of well being, dissipation of work, dissi-

pation of time, on account of sickness and death, and the cost of the sickness being a burden upon the community, a burden eliminated if there were no sickness, and this class is recognized as the third element of loss. Those are the three elements on that side of the equation.

Mr. Wilkerson: You still have made no statement of the value assigned to each of those elements.

The Witness: The problem as it has been worked out by that explanation and analysis is given on this page submitted.

(Handing paper to counsel for the Government.)

(Paper referred to was marked Adams Exhibit 13, and here follows:)

ADAMS' EXHIBIT 13.

19

Loss that would be sustained by the City of Chicago and dependent populations were the present facilities for obtaining an adequate supply of pure water impaired or destroyed, based upon a comparative study of health statistics of the city for 13 years before and 13 years after the opening of the Chicago Drainage Canal.

Per Annum.

Per 100,000 of the Population.

Kinds of Loss.	From Increase in Typhoid Fever	From Increase in Other Diseases
I. By Loss of Contributions to Maintenance:		
a. Through premature death of male workers, 83% of 28.39x36x300......	$254,488	$636,220
b. Through sickness, 83% of (483x10) + (28.39x2) + 52x300.............	23,400	23,400
II. By Decrease in Capital Building:		
a. Through premature death, 42.7x 36x40............................	28,256	70,640
b. Through sickness (726x10) + 52x40	5,581	5,581
III. By Unnecessary Dissipation of Resources: 483x58.41......................	42,405	42,405
	$354,130	$778,246

$354,130x23=$8,144,900.
$778,246x23 = $17,899,658, which is the annual loss to the City of Chicago.

Mr. Austrian: Q. Will you explain that table which is marked Adams Exhibit 13?

A. A full explanation of that table would require a detailed explanation of each of the items in the equations used in arriving at the result.

Mr. Wilkerson: May I ask you this question: Your table here is prepared on the assumption that if a member of the community dies prematurely, the community necessarily sus-

tains a money loss even though somebody else moves into the community the same day and takes his place?

A. Yes, sir; in the same way and for the same reason that a corporation sustains a loss, a railway corporation sustains a loss in case its locomotive is wrecked ten years before its life has expired. It also must use its resources to supply the place of that locomotive. But the resources used to supply the place of the locomotive that is prematurely retired cannot be used in any other way. I think the analogy between a corporation maintaining its property and improving its property and a community maintaining its labor force and extending its labor force is very close.

Mr. Austrian: If you desire, we will have Mr. Adams explain each item and how he arrives at it.

Mr. Wilkerson: Just as you please about it.

Mr. Austrian: If you are going to make the objection—

Mr. Wilkerson: Yes, I think this whole thing, to be perfectly frank, is so much in the realm of speculation it cannot even be included in the evidence.

Mr. Austrian: Expectancy of life is within the realm of speculation.

Mr. Wilkerson: You are assuming that for every man who drops out of a community prematurely, the community has suffered that loss, notwithstanding the fact his place might be filled.

Mr. Austrian: Don't you admit that for every one of the community who drops out prematurely the community suffers a loss?

Mr. Wilkerson: It may be a financial gain to the community.

Mr. Austrian: Will you explain those various items making up the aggregate figure, concerning which you have testified on Adams Exhibit 13.

Recess to 2:15 P. M.

HENRY C. ADAMS, resumed the stand and testified further as follows:

The Witness: Under the first item mentioned in the table, namely, "By loss of contributions to maintenance," there are two sub-items, a: "Through premature death of male workers" and b: "Through sickness." The formula for computing the loss through premature death of male workers is as follows: 83 per cent. of 28.39 multiplied by 36 multiplied

by 300. The 83 per cent. of what will be the result of the computation following that figure in the formula is arrived at in this way: this computation rests upon the loss incident to the premature death of active workers, and it would therefore be improper to include all of the deaths as the computation should confine itself to the deaths from typhoid fever that occur during the working period.

Now, about 83 per cent. of the deaths from typhoid fever occur within the working years, and for that reason only 83 per cent. of the 100 per cent. of computed loss is permitted to enter into the present computation.

The table upon which that percentage rests has already been submitted as Exhibit 4.

The figure 28.39 is derived as follows: as already explained, the decrease in the number of deaths from typhoid fever per 100,000 population since the introduction of the Chicago Drainage Canal is 42.7; this decrease being arrived at by a comparison of the average number of deaths per 100,000 population for the 13 years prior to the opening of the Drainage Canal with the corresponding figure for the 13 years subsequent to that event.

Now, the table of distribution of deaths from typhoid fever shows that males constitute 66.5 per cent. of all deaths. The decrease in the number of males dying from typhoid fever, therefore, is 28.39 per 100,000 of population. That means in effect that the deaths of females are thrown out in this computation, although there are some reasons why females should be included in the productive population, as well as males. But here, as everywhere throughout the computation, I have taken the lowest of the figures that can be used.

The figure 36 is the computed expectation of working life at the average age of death from typhoid fever. This average age for the City of Chicago including all deaths at all ages, is 29.04 years. The average expectation of life for that age is 37 years. If now 65 years be accepted as the average limit of the normal working period, it follows that the number of years lost to a community, of working years, resulting from a death caused by typhoid fever is the difference between 29 and 65 or 36 years.

The next item in the formula is 300. This figure covers that portion of current earnings, the expectancy of which is for a communal or community purpose described in the foregoing analysis. That rests upon the assumption that the general average income representing the productive capacity of workers is some $700 a year. We are concerned here not

simply with workers, men who get wages, men on payrolls of factories, but it is all members of the community, and really you should take into account men who earn from a dollar a day up to men of very high income, all of whom are subject to death from typhoid fever.

The amount that is required for the support of the worker, what you may call the personal expenditure of the worker is deducted from what is called the average productive capacity of individual citizens, and the remainder is accepted as the community loss on account of premature death. That is, the remainder measures the amount that is contributed from the income of the worker to the maintenance of the working fund, and the expense, the personal expense, the demand for or the occasion of that expense dies with the man, but to the extent that while a man is living he contributes to what is the community need, namely, the maintenance of the number of workers, the education and rearing of working men so that they can take the place of workers when retired on account of age that is the community contribution of the individual, and that community contribution of the individual is what is destroyed by a premature death.

I have put it here at the low figure of $300, on the basis of a $700 income. There has been a great deal of analysis and work by economists in arriving at those figures. I do not care to go any further into that unless it is desired that I should do so.

Mr. Austrian: There are a great many authorities on that subject that he can cite to you, if you want them. I think you had better give us those.

Mr. Wilkerson: Do I understand that what the witness has in mind is that there are a number of treatises?

Mr. Austrian: Yes.

Mr. Wilkerson: On that subject?

Mr. Austrian: Yes.

Mr. Wilkerson: Scientific books to which reference is made on this subject.

Mr. Austrian: To which reference can be made.

Mr. Wilkerson: I mean to which he has made reference.

The Witness: No, I have made reference to none as yet. I merely gave my own conclusions from the study of this matter.

Mr. Wilkerson: I thought what was in mind was there were certain kind of treatises to which we can be referred as showing the propriety of the adoption of the $300 figure.

Mr. Austrian: I will not say that figure, but on that comparison.

Mr. Wilkerson: I think we might as well for convenience have here the names of the different gentlemen who have written on this subject. Or if the Professor himself has written anything, if he can refer us to that.

The Witness: From the actuarial point I suppose that Dr. Glover, Professor of Mathematics and Insurance in the University of Michigan, has done as much work as anyone.

Another treatise upon this general subject—

Mr. Wilkerson: What is the title of his book?

A. The title of the pamphlet I have here is, "The Cost of Infectious diseases." But he has a more extended presentation of his theory, which was read before the International Hygienic Congress at Washington, some years ago on the Cost of Tuberculosis in the United States.

There is another article reprinted from the quarterly publication of the American Statistical Association, by William O. Mendenhall, Professor of Mathematics of Earlham College, and Earl W. Castle, of the University of Michigan. This has to do with the monetary losses in the United States due to typhoid fever.

Another recognized authority which summarizes almost everything that has been done on these lines is the Bulletin of the Committee of One Hundred on National Health, being a report on national vitality, its wastes and conservation by Professor Irving Fisher, of Yale University, and of the Commission.

There is another authority upon this matter, Frederick L. Hoffman, statistician of the Prudential Insurance Company of New York. He has published quite a number of articles; and along this line there are a good many contributions made recently for the various life insurance companies, the purpose of which is to justify the expenditure of money in making conservation of health for the companies themselves. I have not a record of all of them, but there are a good many of them.

On the particular question, namely, the estimate of productive ability, perhaps the best authority is Dilfredo Tatreto. He has made a study of the distribution of incomes, and has established what some regard as a law of the distribution of incomes, so that if it is known, according to his law, if it is known what the daily unskilled wage is, he can arrive at the average of the incomes from $300 up to $30,000.

Men like Hoffman usually take $600 as the earning capacity,

and merely say that the earning capacity is equal to the productive ability of the worker; but that includes only the day workers, the unskilled and the low paid workers. And that rests upon the statistics of wages which are very voluminous and very carefully worked out. This law arrives at an income, not only for day workers, wage workers, but for others who create their own wages, pay themselves their own wages, and there the average would be according to this law for a dollar a day something like $700 or $800. I took the lower figure and estimated the amount of personal expenditure, and the difference is recognized as the loss suffered by the community on the occasion of the premature death of any citizen.

The second formula presents the loss on account of cases of typhoid fever which did not result fatally. The 83 per cent. is arrived at in the same way as in the first formula described. The figure 483 represents the number of male cases of typhoid fever which occur annually in the City of Chicago, but which do not result fatally. It is arrived at by the multiplication of the number of deaths, 28.39 by the figure 17, which is the figure accepted as representing the number of cases of typhoid fever for every death from typhoid fever. My authority for that figure is the Pittsburg Survey, and Whipple on Typhoid Fever.

The figure 10 is the number of weeks that each case that recovers is out of work. That assumes that the sickness and convalescence in every case covers at least 10 weeks; I mean that is the average of the cases.

The 28.39 in this formula has already been explained, this being the number of deaths, and the 2 is the number of weeks on the average prior to the time that the death occurs, which is a burden for the community in the same way that the weeks of sickness of those that do recover. This is divided by 52 to reduce it to years and multiplied by 300, which is the figure in the formula already described.

The second kind of loss is expressed in the table as a loss by decrease in capital building. That is, every worker, every member of an industrial community, during his active life, not only contributes to his own maintenance but contributes something to the fund of which he is a part and to take his place when he dies; he not only does that but he contributes something toward the increase of the working fund and towards the higher education, which is equivalent to the raising of the labor, quality of labor. This is the same thing as additions and betterments in the case of an industrial corporation.

This also is submitted under two heads: a, loss through premature death, and b, loss through sickness. 42.7 in the first formula has already been explained. I ought to say before explaining these figures that in this case it is population as such that is taken into consideration, because we only know the increase in wealth and capital on the per capita basis, and therefore it is not the deaths of workers, the working age, but the total deaths from typhoid fever that must be considered.

Now the 42.7 in the equation under A is the average decrease in the death rate from typhoid fever during the 13 years subsequent to the introduction of the Drainage Canal as compared with the 13 years prior thereto. This is multiplied by 36, because this loss continues for 36 years. And the loss per year is computed at $40 on the authority of the United States Census that the increase in capital or valuation from year to year is about $40.

There is also added here a loss because of the decrease in capital building through sickness, which is 726 multiplied by 10 divided by 52 multiplied by 40, all of which figures explain themselves.

The third point in the formula is losses by unnecessary dissipation of resources. That is what is commonly called the sick loss. And I have taken 483 cases of typhoid fever that do not result fatally, and I have taken the result of the Pittsburg Survey, giving 58.41 per case. That seems to me to be unusually low, and so far as I know it is the lowest figure that has ever been arrived at, and I think is too low, for the reason that this Survey in Pittsburg had to do with the poorer people in the poorer districts, whereas, the question we are now interested in covers all citizens of Chicago, of all classes.

The figure 90 has been suggested but the figure 58.41 is the one that is used in this computation.

I think that explains everything in the table, except the question of multipliers. The character and need of Hazen's Law has already been explained, and this table accepts 2½ as the multiplier; that is, it accepts the Hazen Law, as originally stated, and not as modified in figures by Sedgwick and MacNutt and others, who place a higher figure.

In Exhibit 5 there are certain figures that show what the relation is between decrease in deaths from typhoid fever and decrease in deaths from other causes subsequent to the introduction of the Drainage Canal, and the ratio so far as impure water diseases is concerned, as submitted by the Chicago

Department of Health, would suggest that 6.4 ought to be the multiplier. Now, I hesitate to accept that figure, however, for this reason: That these impure water diseases cover diarrheal diseases, and most of the deaths, a very large percentage of the deaths from these diarrheal diseases are deaths of children in early years and this computation has omitted the consideration of any deaths except the deaths for workers.

Mr. Austrian: That is your computation?

A. My computation. Undoubtedly the community does suffer from the death of people who are in the process of education, children, young people who are destined if they live to take the place of workers who are superannuated. This is one point, however, where I omitted an item that ought to be included and shows that the result of my table is below the result that might very properly be claimed as the loss to the City of Chicago should it be deprived of pure water. If 2½ is considered too low of course it can be raised and the conclusions modified accordingly.

Mr. Austrian: Q. These authorities whom you have mentioned, Whipple Tatreto, Hoffman, Sedgwick, MacNutt and a number of others, those are recognized authors upon the subject and recognized authorities upon the subject upon which they have written?

A. Yes, sir, they are recognized by members of their own craft as being specialists in these particular lines.

Mr. Austrian: That is all.

Mr. Wilkerson: That is all.

Adjourned sine die.

Depositions in the above entitled cause taken pursuant to stipulation of counsel for respective parties, before the Commissioner, at the offices of The Sanitary District, Chicago, November 17, 1913.

Appearances:
Mr. Albert L. Hopkins,
Appearing on behalf of the Government
Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
Appearing on behalf of the Sanitary District.

Mr. Hopkins: This agreement about the reservation of objections prevails here as in all the other testimony.
Mr. Adcock: Yes. You mean with reference to taking them up at the hearing.
Mr. Hopkins: Yes.

GEORGE W. FULLER, a witness called on behalf of the defendant, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?
A. George W. Fuller.
Q. Where do you reside?
A. Summit, New Jersey.
Q. Where is your place of business?
A. New York City.
Q. What is your business?
A. I am a hydraulic engineer and sanitary expert, making a specialty of matters of water supply, water purification, sewerage and sewage disposal.
Q. Will you state your education, early training and experience as hydraulic engineer and sanitary expert?
A. I am a graduate of the Massachusetts Institute of Technology. I have made a specialty, since 1888, of sanitary matters relating to water supply and sewerage questions.
I studied in Berlin at the Hygienic Institute, and took a number of special courses relating to the practical art of water filtration, in 1890, in the office of Piefke, the engineer of the Berlin Filters. I then spent some four and a half years

on the technical staff of the Massachusetts State Board of Health.

I was at Lawrence from the spring of 1891 until the autumn of 1895. That station at Lawrence was conducted by the Massachusetts State Board of Health with a view to ascertaining the best means of purifying water and sewage under local conditions in Massachusetts. The tests were conducted to develop the necessary information relating to the laws of purification from an engineering, chemical and bacteriological standpoint. I had charge of the testing station for more than half of the time that I was at Lawrence, having succeeded Mr. Allen Hazen in March 1893, as the man in charge.

I then spent some four years at Louisville, Kentucky and Cincinnati, Ohio, in ascertaining the best means in point of efficiency and economy of purifying the muddy polluted Ohio River water. All these investigations at Lawrence, Louisville and Cincinnati, were reported upon at length, and the reports were published.

Since the summer of 1899, I have been in practice in New York City, and from 1901 to 1911, I was in partnership with Rudolph Hering in the line of hydraulic and sanitary work that I have spoken of above.

During the past fourteen years, I have been connected with upwards of 100 different sewerage and sewage disposal projects, and, roughly, an equal number of water supply and water purification projects. Among the more important sewerage projects with which I have been connected, I can mention the work at New Orleans, where for nine years I was a member of the Board of Advisory Engineers having to deal with the expenditure of some $20,000,000 on drainage, sewerage and water supply projects.

I was also connected with the Passaic Valley Trunk Sewer project in New Jersey, both with regard to getting out the preliminary estimates of cost of that project, to serve about One Million Six Hundred Thousand people, and also have been connected with the litigation before the United States Supreme Court in the matter of the pollution of the New York Harbor waters by that trunk sewer flow.

I have had considerable to do with the Baltimore sewerage and sewage disposal projects; and went abroad in 1906 to collect information as to experiences there bearing upon the local matter.

I have had a good deal to do with intercepting sewers in

a number of large cities, Memphis, Kansas City, Columbus, Schenectady, New York, and elsewhere.

I was connected with the design of the sewage treatment works at Columbus, Ohio, serving also as consulting engineer during their construction, and the first year or two of their operation. I served similarly at Reading, having operated that plant for some two or three years.

I have been connected with sewage disposal designs in perhaps 30 or 40 different instances, the more recent ones being at Atlanta, Georgia, Schenectady, New York, Altoona, Pennsylvania, Norristown Pennsylvania; and a group of cities in New Jersey in what is known as the Plainfield District, and many others.

On water supply matters, I was a member of the committee appointed in 1901 by the United States Senate to consider water supply matters in point of purification of the city of Washington. I served in New York City as consulting engineer, both to the Catskill project and the existing Croton Water Supply.

I have been connected with numerous water supply and water improvement matters for various large cities in this country, including St. Louis, New Orleans, Louisville, Cincinnati, Columbus, Ohio, Minneapolis, Grand Rapids, Montreal, etc.

I have had a good deal to do in connection with appraisal of water works at sewerage projects, having been connected perhaps with 25 water works appraisals, and recently I have been connected with a number of sewerage appraisals; three during the present year.

I have had considerable opportunity to study the art of water and sewage treatment, particularly in connection with appearances as a patent expert in a number of the leading patent suits bearing upon treatment methods. I have followed the development of the art of sanitary engineering in Europe; and have made quite a number of visits to Europe for that purpose. This has been particularly true during the last few years when I have been engaged in getting material for a book upon sewage disposal, which was published in 1912.

Q. Have you had any opportunity to study the conditions relating to the water supply and the sewage disposal problems here in Chicago?

A. Yes.

Q. State what studies you have made and what your op-

portunities have been to become familiar with the conditions?

A. My first opportunity to study sanitary matters in Chicago was in 1893. During the World's Fair, I spent a number of weeks in Chicago, and had charge for a time of the exhibit of the Massachusetts State Board of Health. On that occasion I took advantage of the opportunity to look into water supply and sewage disposal matters, as the various officials here in Chicago were then studying them.

In 1901, I was called in as an expert by the St. Louis Water Department with reference to treatment of the then existing water supply of St. Louis, and that gave me occasion again to review the conditions at Chicago.

In 1903, I was one of the experts in the Drainage Canal litigation, Missouri versus Illinois.

In 1906, I looked into matters here in Chicago with some care in connection with an investigation and report which was made by my former partner, Mr. Rudolph Hering, and myself, to the International Waterways Commission.

In 1909, I had quite a little to do with the testing of a filter plant out in the Stockyards district, and later appeared as a witness in a suit brought by the City of Chicago to restrain the use of the output of that plant for certain purposes in that district.

In 1911 and '12, I made quite a study of the various published documents relating to the Chicago water supply and sewage products, including the report by Mr. Wisner, made in October, 1911; all with a view to embodying the essence of that information in my book.

During the current year, since February, I have had an opportunity to look into this matter in considerable detail as related to the protection of the Chicago water supply and various means of treating the sewage. I have in that connection had opportunity to study up local prices and conditions relating to construction work, and have had experience in that connection through an independent line of work; and that relates to the design and construction of a water filter plant at Evanston.

Q. Your work in 1913, has been in connection with this suit of the Government versus The Sanitary District, has it not?

A. Yes, since February, 1913, I have had occasion to study this problem from various angles, with much thoroughness.

Q. Were you familiar with the conditions which existed here at Chicago in 1889 and prior thereto, in regard to the

opening of the Drainage Canal in 1900, with reference to the disposal of sewage and the water supply conditions here in Chicago?

A. Yes.

Q. I show you a map which is entitled the Sanitary District of Chicago, the map showing the Sanitary District boundaries and corporate limits of Chicago; and ask that it be marked Fuller's Exhibit 1, November 17, 1913. With this map before you, Mr. Fuller, will you explain the conditions which existed here at Chicago in 1889 and prior to 1900, with reference to the sewage conditions and its disposal, and the water supply conditions, for the inhabitants of Chicago and vicinity?

Mr. Adcock: I offer the map in evidence.

A. Briefly stated, in 1889, the sewage of the residents of this community adjoining the lake front, and for some distance back from the lake front, discharged into the lake. The water supply was then taken from a number of cribs connected by a tunnel, and located in Lake Michigan at comparatively short distances from the shore. I speak of distances to emphasize the point that the tunnels were then not so far out into the lake as at present. The sewage from portions of this district removed from the lake shore discharged into the Chicago River and its various tributaries.

There was at Bridgeport an old pumping station of a capacity of something like 1,000 seconds feet; and the purpose of that station was to lift the sewage polluted waters of the Chicago River, and send them through the old Illinois and Michigan Canal down into the Valley of the Des Plaines River in the vicinity of Lockport. The water supply conditions in point of pollution with sewage were notoriously bad, as shown by the records of death rate from typhoid fever and other water borne diseases. The pollution of the lake water at the intake-cribs, where the water was drawn for the public supply of this district was brought about, with substantial regularity, by the flow of sewers discharging directly into the lake. The conditions at certain times were much worse than this, and then the accumulations of sludge in the Chicago River and its tributaries, at times of very heavy rainfall, were flushed out into the lake and unquestionably had a very deleterious influence upon the hygienic quality of the water supply at the intake cribs, and as sent to the water consumers of this general district.

I think that outlines the conditions in 1889, so far as the main features are concerned.

Q. Were you familiar with the conditions of the Chicago River as to whether there was an active nuisance there or not, during that period?

A. Yes, I am familiar with the conditions as existing in 1893, from personal observation, and I have made considerable study of the reports and records and other official communications recording the influence of sewage upon various waterways.

It is a fact that along the lake shore, there were very decided evidences of sewage pollution, and the stranding of sewage solids in putrifying conditions at various points in the vicinity of sewer outlets, along the lake shore. In the Chicago River itself, there was a notoriously bad set of conditions, in point of accumulation of solid matters, of sewage origin. These accumulations of sewage sludge were undergoing putrifaction, and produced what was literally a septic tank.

The so-called Bubbly Creek, for instance, derived its name from the ebullition of gas resulting from the putrifaction of the organic wastes in that branch of the Chicago River. That bubbling action due to the putrifaction of sewage and sludge, or solid matters, caused these solid matters to rise to the surface and form a scum, which the records showed was strong enough to allow men to walk upon it.

In brief, in point of sewage nuisance, the conditions in various waterways in this district were notoriously bad.

Q. I understand you to say that in the time of heavy rains when the run-off exceeded the 1,000 or 1,500 seconds feet of water that was caused to flow into the Illinois and Michigan Canal at Bridgeport, all this sludge, etc., that you have mentioned was washed out into the lake?

A. Large portions of the sludge were so washed out into the lake at times of heavy downpour, and when the flow in the river exceeded the quantity which could be diverted by the pumps at Bridgeport into the old I. & M. Canal.

Q. Do you know whether there were any sewers at that time that were discharged into the lake?

A. Yes, I think there were quite a number of sewers, both on the South side and on the North side.

Q. Were there any of the water intakes that you have mentioned placed further out into the lake, subsequently to that

period; and if you know when they were so placed will you so state?

A. All four of the main intake tunnels have been extended since 1889. My memoranda show that the four mile crib, so called, was completed in 1892. During that same year, the Lake View intake was extended to some 6,000 feet off shore; and in 1896, the Lake View Intake Crib had been extended to about two miles off shore.

In 1892, the 69th street intake had been extended. Another extension there was made in 1894. And in 1910, the Dunne intake crib off 68th street was completed and joined by a bridge with the so-called 68th Street Crib which had been completed in 1894, at a distance of some two miles from shore.

In 1899, the Carter Harrison Crib was completed at a distance of, roughly, four miles from shore.

Q. Do you know what portions of the City of Chicago were served by these various cribs that you have mentioned, with their drinking water supply?

A. Substantially all of the city of Chicago was served by them; the exceptions being very small in significance. For instance, at Rogers Park, there was in earlier years a small intake crib extending some 3,200 feet off shore. I understand that after that Suburb was annexed, it was abandoned as a part of the water supply.

Q. The water is pumped through these tunnels and cribs to the various mains and so forth, from which the people get their water for drinking purposes, is that it?

A. Yes, that is so. From the pumping stations, the water is pumped through the different water pipes in the street. I should explain that some of these tunnels extend under land, and the pumping stations are not in all instances connected at the lake shore. There are a good many land tunnels here in Chicago, but broadly speaking the water from the Lake View, Chicago Avenue, Carter Harrison Intake Crib, the Four Mile Crib, from the two cribs opposite 68th street, the water from those four groups of intakes supplies the water for practically the entire city. I understand that with little exception, in the City of Chicago, there is water taken from no other intake cribs at the present time.

Q. Prior to 1900, did the water that was obtained from these cribs that were built further out in the lake, was it still polluted to any extent by the sewage which discharged into the lake and the Chicago River?

A. Yes, it was.

Q. Now referring to that map, will you explain what works the Sanitary District of Chicago has constructed in the shape of channels, adjuncts, additions to that channel, and intercepting sewers and pumping stations, etc., relating to the disposal of sewage and the protection of the water supply; and if you can state when the different works were completed and what their purpose was.

A. The present main drainage channel was built from 1892 to 1900, and placed in service in January, 1900. It was a waterway starting in the City of Chicago in the vicinity of Robey street, and extended to the vicinity of Lockport, a distance of, roughly, 30 miles. That channel has a capacity nominally to carry some 10,000 seconds feet; and in portions its capacity is 14,000 seconds feet.

At the head of this channel, connections are made with the Chicago River for diverting a flow of lake water entering the mouth of the Chicago River, and with it the sewage which enters the Chicago River and its tributaries.

Prior to the opening of the main drainage channel, there was a reconstruction of some of the main sewers of the city, so that they would divert the sewage from the lake into the Chicago River, or its branches. In 1898, for instance the main sewers on 12th street and 22nd street, were reconstructed and reversed in their slope; that is they flowed into the Chicago River, and no more into the lake.

In 1906, there was practically completed an intercepting sewer on the south side, which took all of the sewage previously entering the lake from the 22nd street district, as far south as 73rd street; and at 39th street, there was erected a pumping station, whereby the flow of sewage from the entire south side was sent through a conduit to the head of the so-called Bubbly Creek. In 1910, this main south side interceptor was extended southward so as to eliminate all lake shore pollution as far south as 87th street. There was a north side interceptor built and practically completed by 1908, for diverting from the lake the flow of all sewers from the northern city limits to Lincoln Park, with the pumping station at Lawrence avenue.

In 1911, the North Shore Channel was practically completed, to allow the diversion from the lake of the sewage from a limited portion of the north shore towns, especially Wilmette.

There was also erected at 95th street a pumping station,

which deals with the sewage flow of a certain area in that general vicinity.

This drainage channel, beginning in its operation in January, 1900, has for its purpose the diversion of the flow of the water of the Chicago River and its tributaries, and the sewage contained in it, so that there would be secured a reversal of flow of the polluted waters away from the lake down the main channel, and into the valley of the Des Plaines River.

Q. Have you been familiar with the conditions that have existed since the opening of the drainage channel?

A. Yes.

Q. With reference to water supply and sewage disposal?

A. Yes.

Q. What conditions have existed with reference to those matters since that time, as compared with conditions that existed before 1900?

A. The conditions have been very materially improved. In regard to the water supply, the building of these lake shore interceptors, and the reversal of some of the sewers at 22nd street and at 12th street, for instance, have resulted in eliminating the effect of sewage pollution in the water supply, and have resulted in the quality of that water being very favorable in its hygienic character, and comparable with the best water supplies obtained elsewhere. In fact, as measured by the typhoid fever death rate, the Chicago water supply is in the very foremost rank in point of purity as compared with any of the large cities in this country, or elsewhere.

In regard to sewage disposal, the present project, which you name in the question, has been completely successful in eliminating pollution and sewage nuisances along the Lake Shore. In the Chicago River and its various branches, the Drainage Canal project has eliminated nuisances to a satisfactory degree and compares most favorably with the success which is found in large cities elsewhere in sewage disposal projects.

Q. I call your attention to the channel known as the Calumet Sag Channel, which is now being constructed, with a capacity of 4,000 cubic feet of water per second. What effect will that have upon the conditions, when completed?

A. The Calumet Sag Channel when completed, and of a capacity of 4,000 seconds feet, will reverse the flow of the Calumet River for a very large portion of the time, perhaps 350 or 355 days in the average year, and in that way will allow a thoroughly satisfactory disposal of the sewage of the Calu-

ment District, and will also prevent pollution reaching the lake through the Calumet River.

Q. What will be the uses of the 4,000 feet of water that may be caused to flow through that channel when completed, for the purpose of protection of the water supply and disposal of sewage of that district and the City of Chicago and vicinity?

A. The first use will be to reverse the flow for nearly all but not quite all of the time with respect to the Calumet River. In other words, there will be a very substantial elimination of pollution in the lake water, which has practical significance with reference to the supply drawn from the 68th street crib, and which now has an element of some significance on account of the pollution which the Calumet River carries to the lake from the Calumet District in Illinois, and also in Indiana. That would be of very substantial benefit as regards the water supply drawn from 68th street intake; and it will also serve in eliminating any sewage nuisances in the Calumet District by the diversion of the sewage from those various centers of population.

It will also serve a very distinct and important use, in that it will bring into the lower portion of the main drainage canal a well oxygenated water, which will be a very substantial benefit in oxidizing the organic wastes coming from the main central portion of the Sanitary District into the Chicago River, and floating down the main channel.

In other words, to state it briefly, water sent down the Calumet Sag Channel with a relatively small amount of sewage entering that water, will be available for oxidizing and satisfactorily treating and putting in an inoffensive condition the sewage originating in the central and northern portions of the Sanitary District.

Q. If interceptors are constructed so as to discharge the sewage of the population in what is called the Calumet District into the main channel at such a point that it will not flow into the Calumet River at high water times or at such times when the run-off is in excess of 4,000 seconds feet, will there be any material pollution of the lake water from that source?

A. No, if the sewage is intercepted and sent beyond regulating works. That is true, of course, of the sewage in this district.

Q. What was the attitude of sanitary experts or sanitary engineers in 1889, as to public water supplies being polluted by sewage?

A. The up-to-date sanitarians were very nearly all of the opinion that sewage should not be allowed to reach public water supplies, as they fully realized that such sewage pollution and infection and the transmission of germ diseases such as typhoid fever were possible and thereby there would be brought about a very grave menace to the public health of the community drinking such sewage polluted water.

I might say in this connection that in 1889, there was being brought to a close a transitional period between what was known as the filth theory of disease and the germ theory of disease. Up to the early eighties, sanitarians knew that water supplies which received sewage and other filth were prejudicial to the public health. They did not know just how that was brought about. During the eighties, the medical men interested in scientific sanitary matters developed the theory of the causation of disease through the bacteria or specific germs for the respective diseases. There were a few of the leading medical men, and a few of the most prominent of the sanitary engineers, who in 1889, were of the opinion that sewage pollution gave opportunity for the transmission of intestinal diseases, to the consumers of water which had been so polluted with sewage; but it was several years after 1889 before there was a general recognition of the germ theory of disease by the medical profession and by the more intelligent laymen and by the engineers as a group of professional men.

Q. They have that same idea at the present time, haven't they?

A. They have yes, and with a wide range of actual observation and fact to support the proposition that water supplies are not safe when they receive sewage pollution.

It was a few years after 1889, when the severe epidemics of typhoid fever in the Merrimack River Valley in Massachusetts and elsewhere, and when the cholera epidemic in Hamberg showed most conclusively that it was a grave menace to public health for a community to be supplied with drinking water, sewage polluted, and containing the germs of disease.

Q. What was the state of the art of water purification, protection of water supplies from sewage pollution in 1889?

A. As regards the protection of water supply, the larger cities having the foremost sanitary advisors, recognized the importance of keeping sewage out of water supplies. That was about the date when the early beginnings were made of separating sewage from water supply. In some instances, efforts were being made to locate new intakes for cities situated

on rivers, so that the water would be taken from above the discharge of sewage. It was recognized that where this was not feasible, intercepting sewers should be built for river cities, so that the sewage would enter the stream below and not above the river intakes.

There was at that time nothing known at all about the sterilization of public water supplies. In this country, there were practically no water filters in towns of any considerable size. For 20 years the art of water purification had been dormant.

In the late sixties, Mr. Kirkwood, one of the leading American engineers, studied water filters as practiced in Europe, and had made an extensive report in the interests of the City of St. Louis. It was not thought wise, however, to build filters from information then available.

There were one or two filters built in the Hudson River Valley at Poughkeepsie and Hudson, New York, but with that exception, there were no sand filters in existence in this country.

Mechanical filters, as now known, were practically unheard of and were then merely crude straining arrangements in use in mills and other industrial establishments, with a few scattered plants that were just beginning to be installed for some municipal supplies. In those days, the germ theory of disease, as I have already explained, was not generally recognized; and while there were sand filters in Europe, they were essentially clarifying devices, and the benefit to the hygienic quality of the water appeared to be a mere incident. In other words, there was practically nothing known in the art of filter filtration which had associated with it well defined laws which would allow hyigenic accomplishments to be reliably secured. American engineers were afraid of water filters in those days, owing to the wide differences in climatic conditions as compared with European facts and conditions; and furthermore they had nothing to serve as a practical guide as to how they should build the filters to secure effective accomplishments at all times, under the wide range of local factors, climatic, and relating to the water itself.

I can best illustrate the negligible working art of water supply in 1889 by saying that I was at that time connected with the Massachusetts State Board of Health, and even a little later on their attitude was one of not knowing how to advise the City of Lawrence to filter a grossly polluted water supply, at a time when severe epidemics of typhoid fever were raging.

In fact it was not until 1892 that experiments even were

made at the Lawrence Experiment Station to work out what might be called the laws of filtration, which are the basis of water filtration of subsequent years.

Q. What is your opinion as to the hygienic improvement in the Chicago water supply due to the drainage canal and its appurtenances, in comparison with what may reasonably have been secured with water filters and other means of improving the local water supply, as known to the art of 1889?

A. The hygienic improvement in the Chicago water supply due to the Drainage Canal is decidedly greater and better than could have been obtained by improving the water supply in other ways as known to the art of 1889. In other words, the diversion of the sewage from the lake and from the Chicago water supply was far better than to have attempted to try any other means for getting a pure water supply, as those means were known in those days.

Q. What methods of sewage disposal were available to cities at that time?

A. There were three methods that were studied for large cities. There was the dilution method, which was by far the most prevalent method, and there were available two other methods which had been tried somewhat in certain of the European countries where large centers of population had sprung up upon very small water sheds. Those methods other than the dilution method were known as chemical precipitation and land treatment. In explaining those two latter terms, I will say that land treatment grew out of an effort to apply sewage to farm lands, in order to take advantage of the manurial properties of sewage.

It had been tried, for instance, here in the Chicago district, at Pullman, and it was found that the land was not suitable for such purposes.

In regard to chemical precipitation, that was a method of applying certain chemicals like lime, alum and iron sulphates to sewage, allowing the treated sewage to pass through tanks holding several hours' flow; and in the tanks there would be deposited the course sewage filth. Those chemical precipitation works in England that were then in existence, had their origin also in efforts made commercially to secure the manurial properties of the solid sewage substances. They were not a success commercially, as to the securing of fertilizing properties at a cost which would be at all warranted on a large scale. They were essentially clarifying arrangements, and were then in considerable vogue, owing to the efforts made in

London to clear up the lower Thames, which had very foul decomposing banks of sewage sludge in its lower reaches.

I might say that there were some little contrivances, called clarifying or straining arrangements, which were practiced at places like Atlantic City and Long Branch, in order to keep the sewage solids away from the more prominent sea shore bathing beaches, but they were very short lived and are not worthy of any serious consideration in a project such as then existed at Chicago.

Q. Was the chemical precipitation method of any use in rendering the sewage inocuous, or less dangerous to water supply?

A. It tended of course in that direction, but it did not produce a treated product so that you could safely discharge that treated sewage, clarified sewage into a stream or into a lake and have a safe water supply. It was a clarifying process and not one for removing completely disease germs. In fact it was applied, not with a view of protecting water supplies but solely to eliminate sewage sludge, prevent these foul decomposing masses of sludge, and that alone was its true function. It was not a means of protecting a source of water supply.

Q. What has become of the sewage farming method in this country, how has it been used if at all?

A. It has never been used with any success commercially. In fact, the method, even in our arid western states has had a very limited and merely nominal scope of usefulness. The reason of that is that it costs more to get the sewage to farm lands surrounding a large city than is the worth of that sewage for fertilizing purposes, or for irrigating purposes, or for the two combined. That is very well demonstrated by the experiences of Los Angeles, for instance.

Twenty years ago, the sewage from the outfall sewer at Los Angeles was used in sewage farming, but the resentment of the public to having garden truck come in from districts where it was known that sewage was used on the farm lands, the odors which arose from the pooling of the sewage on the farms, and the interference with land development projects even miles away from sewage farms, all led that city, with a rainfall of only ten or twelve inches per year, to abandon sewage farming and build a new outfall sewer to the Pacific Ocean.

What I have said with regard to Los Angeles applies, I think, to every other sizable city in our arid districts. It is not difficult to find references in official publications to some

nominal use of sewage for sewage farming in the western states, but a careful examination such as I have given to these subjects, shows that the sewage has been used simply for its irrigating purposes, at times when it would be of benefit to the farmer, and that on other occasions it has been diverted to the nearest water course.

In our eastern states, the matter stands in quite a different attitude, because the rainfall is generally sufficient for farming purposes, and when there is ample rainfall the farmers are in all cases disposed to divert the sewage to some water course, or to allow it to build up on certain portions of the farm lands where it putrifies and produces nuisances.

Briefly stated, the attitude and experience in this country with regard to sewage farming, I would say that the method has never become well established, even for small cities, and it is entitled to no established footing or standing for the problems of large cities. That is true in the west, and still more so in our eastern states.

Q. Will you describe briefly the state of the art, the development of the art of sewage disposal, if there has been any development from 1889 to the present time?

A. In 1889, I take it all sewage was disposed of by dilution. There are some instances where sizable towns have grown up on very small streams, where treatments works of some kind or another have come up for consideration, but today it is safe to say that somewhere from 93 to 96 per cent. of the sewage of all towns and cities is disposed of by dilution. Where it is not so disposed of, the dilution method is not a candidate for consideration, because of the small volume of water available for diluting purposes.

There are a few other exceptions along harbor towns, for instance, where shell fish pollution has been a factor.

Broadly speaking then, the dilution method which was practically in universal use in 1889, has continued to be the prevailing one. In fact it is always applied to-day where the conditions allow of its being applied under reasonable conditions.

The sewage farming method that I have spoken of already is on the wane decidedly, in Europe. The largest sewage farm in England, at Birmingham, has been practically abandoned. In Paris, it is being gradually given up, and, beginning a couple of years ago, they are installing sprinkling filters to take the place of sewage farms now located in part in the growing suburbs of the district.

In Berlin, the sewage farms are still used, where the conditions are very favorable as regards light, sandy, porous soil, on lands that were purchased many years ago at a very low price, and where the rainfall conditions allow the irrigating value of sewage to be taken advantage of, in a way that does not exist in our eastern or central states. The increment of land value alone at Berlin seems to justify a continuance of a method which is expensive at best.

Q. Does the consumption of water per capita in Berlin, as compared with that in the cities of the United States, have anything to do with that problem?

A. Yes, it has quite a little to do with it. The amount of water consumed in Berlin is only about 30 gallons per capita as compared with 200 gallons and more found in many of our American cities. That has a good deal to do with the cost of intercepting sewers, pumping stations, and works for delivering the sewage to the farms. And it requires a much smaller area per capita in European cities than would be required in our American cities.

Chemical precipitation works in 1889, had been recommended for adoption in Providence, and those works were built after an interval of some 14 years, put in service in 1901, following the recommendation for adoption in 1887. Their purpose was to eliminate sewage mud from the Providence Harbor, and to prevent the foul decomposing conditions there found.

That method of chemical precipitation at Providence, was continued until a year or two ago, when it was superseded by plain sedimentation and sterilization of the sewage, for the purpose of protecting the shell fish layings in the Providence River below the outfall from the treatment works in the deep water at Feild's Point.

At Worcester, under orders of the court as the result of litigation on the part of the riparian owners in the lower Blackstone River, the City of Worcester about 1889 started to build chemical precipitation works, which were completed in 1891. Those works were enlarged a few years later, and are in service today to treat some of the sewage, which, for the most part however is now being treated in works of more modern, economical and efficient design. The few little chemical precipitation plants around Coney Island, and some of the beaches of greater New York, at Canton Ohio, East Orange, New Jersey, and a little plant in the Mystic Valley just outside of Boston, have all been abandoned.

It is a fair general statement to say that the chemical pre-

cipitation method has no standing today in this country for disposing of sewage as regards elimination of sewage nuisances, except perhaps for some small problems where there are complicated trade wastes. Its day has come and gone, and I think that statement applies also to the large European cities generally speaking. It is certainly true of London, where this method of chemical precipitation received its greatest impetus in the late eighties.

Since the days of 1889, there has been quite a substantial advance made in treatment works for sewage, that has come in as the result of the pressing needs of some communities located on small streams, where the dilution method could not be satisfactorily applied.

Q. In order to remove a nuisance in those streams?

A. Yes, in order to remove a nuisance in the streams.

Continuing the developments of the art since 1890, I will say that various methods have come up for the consideration of the solution of sewage treatment problems. From about 1895 to 1900, the so-called single story septic tanks were in vogue. Their purpose was to remove the solid sewage filth, and allow it to become septicised, and in early days it was assumed all solid sewage filth could be liquified, and gasified by bacteria. Practical developments have shown that this was not feasible.

More than that, the practice with large cities has shown that very severe complications in point of nuisance have been brought about, as the odors from septic tanks have arisen.

Recently, septic tanks of the single story type, built so frequently a dozen years ago or so, have been practically abandoned for all large municipal projects. Within the last year, there has been put in service at Atlanta a two story tank, a settling and septic tank, which has proved to be of much practical benefit, according to the data now available. This is the method of clarifying sewage that has superseded both the chemical precipitation of 20 years ago and the single story septic tanks of a dozen years ago.

In regard to methods of oxidizing those portions of sewage which are either in solution or will not settle in settling tanks, there has been a radical change in the art from 1889, when sewage farms were almost exclusively used.

First there was developed in Massachusetts the intermittent sand filter, where sewage was applied to large areas of porous sand found in place in sections where glacial drift formation was noted. In the central, western and southern states, that method had no footing because the porous sandy

deposits did not exist in place, and the method was found to be too expensive when sand beds had to be built artificially.

Next, there came about 1900, the so-called contact bed in which beds of stone were filled with sewage, and allowed to have the pores stand full of sewage, for a few hours when the bed was drained and allowed to have its pores filled with air. That method was found to be prohibitively expensive for large projects, and its use today is confined to small communities in residential districts, where the effort is to minimize the odor question.

In places where water cannot be made available for oxidizing clarified sewage, so as to prevent sewage nuisances, it is found that the so-called sprinkling filters are the best means of making sewage stable or non-putrescible. By that I mean the treatment of sewage, so that it will no longer putrify after treatment, and after standing for an indefinite period. These devices are large beds of stone, perhaps one to three inches in diameter, and six feet or more deep, and on to which the sewage is thrown in the form of a spray from numerous spray jets, spaced perhaps ten feet apart, over the surface of the bed. The practice has shown that these devices will produce a non-putrescible effluent; but it has also been found, at Columbus and elsewhere, that unusual care must be taken for large projects, to keep the sewage in a fairly fresh condition, so that very serious odors will not arise in the neighborhood of the sprinkling filters. These odor factors have not been encountered in the smaller plants, and in a large scale, the art now shows means of guarding against the odors by keeping the sewage well aerated, and thus arresting putrifaction of the liquid before it meets the sprinkling filter beds.

In the general developments of the art of sewage treatment works, practice has shown that it is much more expensive to build and operate these works on a satisfactory basis than was anticipated a few years ago. In fact, the experiences of the past year or two indicate clearly that projects now in service involve considerably larger sums of money than the earlier estimates indicated.

One other factor I should mention in the art of sewage treatment works, and that is the sterilization of sewage to attempt to destroy disease germs.

Nothing was known of sewage sterilization on a practical scale until about 1906. It was then tried at Red Bank, New Jersey, to apply hypochlorite of lime in settling tanks to sewage with a view to reducing the number of disease germs in

the liquids that were sent out in tide water, in the vicinity of shell fish layings. There have been a number of projects recommended for the sterilization of sewage, but so far as I know there is no instance where large cities have made public any records as to experiences in the systematic sterilization of sewage. The nearest approach to it is at Providence, that I have already spoken of, and where they have abandoned chemical precipitation and started out on a tentative scheme of using their tanks to settle the sewage and to apply sterilizing processes in the interests of shell fish layings in Narragansett Bay.

I have been told also that recently the City of Toronto is attempting to sterilize its settled sewage before discharging it into Lake Ontario.

With regard to the dilution method, the greater attention given to sanitary matters in various parts of the country have shown that it was applied in earlier years with many shortcomings. By that I mean that sewer outlets were built into water courses to a very unsatisfactory degree. There are many American rivers and lakes where sewers reach only to within 100 feet or so of the waters edge, and show a pollution which has given rise to offensive conditions that do not exist or would not exist if the sewage had been well mixed with available water for dilution.

It is also found in some places that sewage has built up sewage banks or sludge deposits, which could be remedied with a little care.

So in brief, the dilution method in my opinion, as the result of careful study of the various engineers, now applying it on a more rational basis than in earlier years, is now on a firmer basis than ever before.

It is true however that it is suffering, in the public mind at least, from the poor reputation it got in earlier years, when it was applied in a very inadequate and haphazard fashion in a great many cities, with attending nuisances as to odor. Today I believe it is entitled to far more consideration than ever before, and I think that engineers in approaching these problems will give it in many cases more careful consideration than they would have done a short time ago, when it was not so clearly appreciated as to what the conditions were under which it could be used, and take advantage of its economy and allow local nuisances not only to be eliminated, but to allow them to be eliminated in a way that they would not be transferred to other neighborhoods.

Q. Have you considered the adequacy of the minimum

ratio of dilution, that is to say 3.33 cubic feet per second per thousand population, that is prescribed by the act under which the Sanitary District of Chicago is organized; and if so will you state your views upon that problem?

A. Yes, I have considered this ratio; and in my opinion it is as low a ratio as it is feasible to employ, when consideration is given to the domestic sewage of a community.

If I were to consider any change in this ratio, I should be disposed to increase it. That ratio makes no provision for trade wastes; and if trade wastes were to be considered as well as the domestic sewage, I believe this ratio should be increased.

I have looked into this matter with considerable care; have been down the length of the Drainage Canal, studied the records on many occasions. I am making this statement now with respect to conditions as applied to the Chicago Drainage Canal.

Q. To what extent have you taken trade wastes into account in your study of Chicago problems, and what are the reasons for your position, and in this connection will you describe what you mean by the term "trade wastes"?

A. I take trade wastes to mean those products which arise in large industrial establishments, for instance tanneries, packing houses and slaughter houses, where the wastes are removed by water carriage, are substantial in quantity, and are entirely different from what you would get in sewers, which drain the ordinary residential community, with the wastes that would come from business blocks, commercial enterprises and small manufacturing establishments where the wastes that went into the sewers were merely nominal in amount. As applied here particularly to the Chicago problem, it relates essentially to the waste coming from the Stockyards district and to the tanneries and to the other establishments along the North branch.

Now, in this problem, I have given no consideration to the trade wastes item. The reason for that position is that the disposal of trade wastes is a matter which applies with equal force, whether on the one hand you are considering the dilution method for the local problem, or whether there are considered treatment devices for disposing of the sewage other than by dilution methods.

In other words, it is an item which appears on both sides of the equation in these dilution projects which I have studied; and being the same item on each side of the equation, it properly drops out of consideration.

I might further say that it is my understanding that the Drainage Canal here was projected on the basis that trade wastes were not to be a factor ultimately in dilution ratios, or in other aspects as regards sewage disposal. It is a fact, however, that trade wastes have gone down the Drainage Canal, as an incident to the period during which the volume of domestic wastes has not required the amount of diluting water equaling the capacity of the channel.

I understand further that in the Department of Engineering of the District, there has been established a division, the purpose of which is to study various methods for treating trade wastes, without, however, any consideration, so far as I know, of the financial arrangements under which such treatment methods would be applied.

Q. Taking into account all the facts and conditions that you have mentioned relating to the Chicago Drainage Canal, referring to the protecting of the water supply and preventing sewage nuisance, what is your opinion as to the standing to which the Drainage Canal project is entitled, when viewed in the light of the art of 1889, and also today?

A. In my opinion, the protection of the Chicago water supply is secured in a more simple, effective, economical and therefore better way, than could be secured by any other means of treating the sewage than by the present method; and that applies to the art of 1889, and also to the art as known today, in the matter of sewage diversion and sewage treatment.

Q. Assuming that the flow of water from Lake Michigan through the Drainage Channel, or its adjuncts, were restricted to 4,167 cubic feet per second, what would be in your opinion the consequences with reference to the water supply and sewage disposal problems of Chicago?

A. Such a reduction in the flow of lake water through the main channel and its adjuncts would create a profound and unfavorable disturbance in the fundamental principles upon which this project was designed and built. They would relate to several factors, which I will speak of in turn.

First, a flow of water from the lake of 4,167 seconds feet would defeat the main purpose of the channel, which is to secure at all times a reversal of flow of the Chicago River, in order to protect the water at the intake cribs of the Chicago water supply.

In other words, at times of very heavy rainfall, there would be a reversal of flow of the Chicago River carrying the river water and considerable sewage out into the lake, such as was

the condition of affairs prior to 1900. That reversal would occur on a good many days in the course of a year; at least ten in the ordinary year, and a much greater number than that during years of abnormally high rainfall, or having periods of unusually high rainfall.

Q. What would be the conditions with reference to the reversal of the flow of the Calumet River, with the flow limited to 4,167 seconds feet, and assuming that the Calumet Sag Channel were completed?

A. That of course depends somewhat upon the relative volumes of water that would be sent down the main channel from Robey street as compared with what went down through the Calumet; but it is reasonable to assume that under ordinary conditions of operation there would be substantially no reversal of flow in the Calumet River.

Proceeding now with my answer to the next to the last question, I wish to point out that even on the assumption that at times of heavy rainfall the flow down the channel would not be limited to 4,167 seconds feet, that, in a practical working way, this does not modify my statement above as to inability to secure a reversal of flow of the Chicago river such as is necessary in order to protect the Chicago water supply. The reason for that is that it takes a good many hours, half a day or so, in order to change the regulating works at Lockport so as to increase the volume of flow in the vicinity of the Chicago river down into the main channel and into the Desplaines river. It is this lag of half a day or so, which in my opinion would prevent the practical operation of the Drainage Canal in times of storm flows, so as to secure the protection that now comes from the present method of operation with respect to preventing sewage getting to the intake cribs.

A third aspect of the proposition, assuming 4,167 seconds feet diversion from Lake Michigan water through the main channel and its adjuncts, would force to consideration other means of treating the sewage, whih now is disposed of by the dilution method. That flow corresponds to the legal minimum ratio of dilution for about 1,250,000 people. Obviously the domestic sewage from a population in excess of that figure would require treatment works, or other means of eliminating sewage. This last proposition involves two aspects: One is the feature of the dilution of sewage, so as to prevent putrification of the flowing sewage; and in the second place, with this assumed reduction in the flow of Lake Michigan water, the velocities in the waterways of the channels, main channel,

Chicago River and the various appurtenances would be reduced so that the solid sewage matters would become stranded to an extent where sewage mud banks would arise, putrify and produce seriously offensive odors.

To my thought, it means that with this reduced flow of lake water it would be necessary to settle all of the sewage so as to keep the sludge out of the waterways, as well as to provide means of protecting the water supply through the sterilization of all sewage. And it would further mean the use of sprinkling filters, or other devices, for rendering stable and non-putrifactive the flow of sewage in excess of that which could be properly diluted with this 4,167 seconds feet of lake water.

Q. What are the remedial measures that could be taken to protect the water supply of Chicago, in the event that the flow of lake water were reduced, or limited to 4,167 cubic feet per second?

A. There are two styles of procedure, or two projects which could be adopted for protecting the water supply of Chicago and eliminating sewage nuisances.

The first of these (which I will call A) would involve the collection of the dry weather sewage flow and the first flushings of storm flows, after they pass through settling tanks and apply them to sprinkling filters, so as to render the sewage non-putrescible.

The sprinkling filters should be built to take care of the sewage flow from such portion of the population as could not allow its settled sewage to be adequately diluted by the 4,167 seconds feet of lake water. It would be necessary in protecting the water supply to sterilize this flow of sewage after its treatment by settling or sprinkling filters, or both; and it also would be necessary to sterilize the storm overflows at times of very heavy rainfall. The reason for this sterilization would be that if it were not sterilized some of this treated sewage or storm overflow, or both, being present in the Chicago River and its tributaries at the beginning of heavy downpours, would be sent out into the lake at times. Therefore, to be on the safe side and reasonably to protect the water supply, it would be not only necessary to settle or filter the sewage to guard against nuisance day by day, but it would also be necessary to sterilize these liquids to protect the water of the lake at the intake cribs.

There is a second method of procedure (which I will call B) which would be a project involving, in the first place a sys-

tem of separate sewers throughout the district for collecting the household wastes. That would mean a new set of sewers on all the streets where sewers now exist. It would mean that the rain water falling on the streets and roofs and various areas, yards, vacant land and parks, would reach the water courses through the present system of sewers; and that all house connections for all the properties of this district would be disconnected from the present system of combined sewers and shifted over to the proposed system of separate or sanitary sewers. The flow of such a proposed system of separate or sanitary sewers would then be treated by sedimentation and filtration to secure a product which would not produce putrificative conditions in the channel, and this flow would also be sterilized.

Under this arrangement, the storm water which would reach the water courses through the existing system of sewers would go there without any treatment of any kind.

Q. Describe the different types of works that you have mentioned in connection with the two projects?

A. As these two projects have been developed, it is necessary, first, to state how the sewage would be brought to various places for treatment.

I will speak first of project A, in which the flow of sanitary sewers would be through the existing present combined sewers. Speaking generally, there would be intercepting sewers, which would run along the margin of the Chicago River, and at some other points, picking up the sewage from the lake front. These intercepting sewers would receive the settled sewage which would flow from the sewers as they exist today. By that I mean that the sewage flow would be led into settling tanks before it discharges into the water courses. This ordinary dry weather flow and the first flushings of storm water would then pass from the tanks to intercepting sewers. These intercepting sewers would lead to sprinkling filter sites in most cases, where the sewage, with some intermediate pumping, would all be lifted at the end of the intercepting sewers on to sprinkling filters, where it would be applied to beds of stone through various spray jets.

Speaking generally now of locations—I am looking at the map marked Fuller Exhibit 1, November 17, 1913—I will call attention to the fact that along the north branch, for instance, intercepting sewers would be built from Kinzie street on either side of the north branch to a point above Fullerton avenue, where the conditions would allow sedimentation tanks to be

built. There are some sixteen sedimentation tanks which would be required along the north branch north of Fullerton avenue. The flow of sewage from these settling tanks would be into interceptors, which would lead on either side of the river to about Lawrence avenue. Thence they would unite in a single interceptor built, leading to a proposed sprinkling filter area, just north of the city limits between Devon street on the south and Tuohy avenue on the north. This area lies immediately west of the present north shore channel.

These intercepting sewers would be built of a capacity of about 900 gallons per capita, with a population estimated as of 1930 for the various areas tributary to these respective sewers.

There are, besides this so-called Lawrence avenue project, for treating the sewage north of the Chicago river, three other projects. The second one, spoken of as the West Side project would involve the collection of sewage from the Loop District, and an intercepting sewer which would run along the west bank, or near the west bank of the Chicago River, to the vicinity of Western avenue. There the settled sewage, which at various outlet sewers would pass through settling tanks and into this interceptor would be lifted from the interceptor to settling tanks located between Western avenue and Kinzie avenue beyond the Bridewell; and thence the sewage from the western portion of the city in the sewers now existing and located north of the main channel would likewise return to this main settling tank.

Sprinkling filters, so fas as required would treat the settled sewage from this main west side plant at an area located north of the main channel, south of 39th street, and between South 64th and South Harlem avenues. These sprinkling filter sites in all instances are colored brown on this map.

The third main project, spoken of here as the 39th Street Project, would receive the sewage from the various sewers tributary to the present 39th Street Pumping Station. There on the lake front, settling tanks would be located, the flow of which would be pumped through a conduit which should receive also settled sewage from various main sewers in this area lying south of the Chicago river, excepting the Loop District, and south of the main channel. This settled sewage would be delivered for treatment in sprinkling filters to an area immediately south of that which I have previously described, that is south of the main channel, and lying between South 64th avenue and Harlem avenue.

There would be needed in this instance several pumping stations and settling tanks for the Stockyards District and for the various sewer outlets now discharging into the river or channel, and not tributary to the main pumping station at 39th street.

The fourth project, spoken of here as the Calumet Project, would involve an intercepting sewer starting in the vicinity of the 95th Street Pumping Station, taking the flow from the various centers of population in the Calumet District and leading to springling filters lying just north of the Calumet river, south of 130th street, and lying immediately west of Cottage Grove avenue extended south. On this system of intercepting sewers, there would be settling tanks at the outlets of the various sewers and a number of pumping stations, all of which will be detailed in the estimates which I will consider later on.

On this map, the intercepting sewers are marked in red showing their location, and also with an arrow indicating the direction of flow.

The sewage pumping stations, at points where it is necessary to lift the sewage flow along the line of the interceptors, are shown with black circles, and the same black circles are used to indicate the pumping stations needed for lifting the sewage at each of the respective sprinkling filter sites. The sedimentation and disinfecting plants are shown in yellow with a heavy black margin around the area, and as I have already stated, the sprinkling filter areas are shown in brown.

I should explain that at all of these settling tanks, the flow of the sewers in excess of 900 gallons per capita for the 1930 population would have disinfection or sterilization plants where such excess storm flow would be thoroughly disinfected.

Now, proceeding to what I have called the other project, Project B, the various treatment works would be located at the same areas as I have just described for Project A. The intercepting sewers, however, would be smaller because they would deal only with the domestic wastes and not receive storm flows. They would be, roughly, half of the capacity of the interceptors of Project A. The pumping stations would also be smaller in size, on account of having no storm water to deal with.

I have assumed that the settling tanks, sprinkling filters and the interceptors, in point of location, would all be located precisely as in Project A.

By Project B, there would drop out of consideration, how-

ever, the disinfecting plants as regards storm water flows; but the treated sewage would in all cases be subjetced to sterilization.

One further word about the sterilization should be added, and that is that where the sewage is subjected to treatment in sprinkling filters, the sterilization plant would deal with the filtered sewage after it had been subjected to a secondary sedimentation.

In those cases where the sewage is not passed through sprinkling filters, the disinfection would take place at the primary settling tanks, and adjoin the works for sterilizing storm overflows in Project A.

Recess to 2:00 P. M.

After recess, 2:00 P. M.

GEORGE W. FULLER, resumed the stand and testified further as follows:

The Witness: (Answer continued.) This map marked Fuller Exhibit 1, shows also a small project marked here the "North Shore Project," wherein is shown a system of intercepting sewers beginning in Glencoe near the northern district boundary line, coming through Winnetka, Kenilworth, down to Wilmette; there showing a pumping station and small treatment works for a population of 55,000 people estimated as of 1920.

In regard to the collection of the sewage flow from the present sewers discharging into the various water courses, I should state that in these intercepting sewers and appurtenances arrangement is made for aerating the sewage. The purpose of that aeration is to prevent putrification taking place such as is found in a great many outfall sewers of large cities, owing to the age of the sewage. Now, to prevent and offset the putrification, which is due to bacterial processes taking place as the liquid flows in the sewer, provision is made in these projects for pumping in air so as to keep the decomposition on an oxidizing and not on a putrifying basis.

With respect to the population, it will perhaps be more explicit to repeat a word or two, and say that these intercepting sewers for delivering the sewage flow to settling basins, sprinklers and treatment works, the design has been based on the assumed populations of 1930, namely 3,500,000 people. With respect to the treatment works, this is including the filters,

settling basins and sterilizing arrangements, the population has been assumed as of the date 1920. On that date, the estimates of population show for the city a population of 2,900,000. In fitting these different projects to a population basis, there has been some little latitude used and there has been included the population of the Calumet District on the south and the North Shore district on the north.

The population provided for in my estimates is: Within the city, 2,900,000 population; outside of the city limits, in District 14 on the west side, 133,000; 21,000 outside the city limits in the Calumet District, and in the North Shore District 55,950. The latter figure includes Evanston.

Now, the summation of all of these different populations assumed to be provided for in the respective treatment works amounts to roughly 3,000,000. I have assumed in my estimate that that would be equivalent to what would be served by 10,000 seconds feet flow in the main drainage canal, equal to 3,000,000 people.

I am aware that in making estimates of future growths of population in different districts there are bound to be some discrepancies, and these aggregate figures are rather more liberal than should be made for the respective individual treatment plants.

I think next I will outline briefly the particular devices which it is proposed here to use in settling and filtering the sewage, and in sterilizing it; and refer roughly to what in practice elsewhere these particular devices have accomplished in the nature of improving the hygenic character of the sewage, and with regard to the bearing which the works would have upon the elimination of sewage nuisances.

The settling tanks would be built of the two story Imhoff type. By that I mean that there would be large settling tanks built with their flow line roughly corresponding to the flow line in the existing sewers. They would have a depth of some 25 feet, say, and be in two stories. In the upper compartment, the sewage would flow through the tanks for a period on an average of two hours. The increase in the cross-section of that settling compartment with respect to the size of the sewer so checks the velocity down to half an inch per second or so, with the result that there are deposited the coarse matters in the sewage.

In the bottom of this campartment is a slot or opening, through which the solid matters would pass to a large chamber beneath. This lower chamber is called a digestion cham-

ber, and in it the solid matters would be allowed to accumulate for perhaps six months or so. During this interval bacterial decomposition would intentionally be directed and encouraged, so that it would gasify, putrify and allow the bacteria to eat up all of the unstable organic matters. Much of this solid matter would be changed to liquid and gaseous substances. The result of this is that the sewage sludge would become septicised or eaten over by the bacterial life, so that it would be taken out in a substantially inodorous condition.

This wet sludge from the lower compartment would be removed at intervals through a pipe, and applied to little thin beds of sand and gravel; and it so happens that the sludge as removed contains much gas. This is of importance, because when it is removed and applied to these straining beds or sludge beds, the gas seems to lift the solid matter to the surface, and it allows the liquid from the bottom to pass down through the sand and gravel of the bed to which it is applied. In the course of a week or so this septicised sludge has been so freed of water that it is spadeable, and can be shoveled into containers for its removal to any convenient place to be used for filling, or to be stored in a spoil bank.

At these settling tanks along the various sewer outlets going into the water courses, arrangements would be made whereby the sewage flow passing through the tanks would be limited to three times the dry weather flow, or to 900 gallons per capita daily. The storm flow in excess of that quantity would not pass through the regular settling tanks, but would be subject to sterilization. By sterilization, I mean that there would be added to the storm flows liquid chlorine sufficient to kill the disease germs in the liquid and upon the exterior of particles of suspended matter. Sterilization is, of course, not effective in killing the germs in the interior of particles of suspended matter.

These tanks for purposes of sedimentation would allow the removal of some 90 per cent. or so of the particles which are capable of settling. They do not of course affect at all those soluble matters in the sewage, such as urine, nor the fine particles of fecal matter, or substances of other origin which are so fine that they will not subside. That is the non-settling solids and the soluble matters in the sewage pass through the settling tank and on into the intercepting sewers.

In the course of six or eight hours or so, sewage will become, under ordinary conditions in large cities, putrifying, and productive of foul odors to an objectionable degree. These

intercepting sewers are supposed to carry sewage which has its content of oxygen not depleted; and the oxygen supply is assumed to be replenished by pumping air at intervals into the flowing liquid in the intercepting sewers. The quantity is, in accordance with various tests at New York, roughly, one-tenth of a cubic foot of air to one gallon of sewage.

In those cases where the settled sewage must be filtered, that is for all projects other than the West Side Project, the settled sewage will flow in these intercepting sewers and be pumped at the respective filter sites on to the sprinkling filters. I should say that for the West Side, I have assumed that the settled sewage from the central west side area, from the Loop District and the floating population in the Loop District of some 300,000 people, that that settled sewage could be adequately diluted by 4,167 seconds feet flow of lake water, so that it would not be necessary to filter it.

The removal of organic matter by sedimentation is taken to be roughly 25 per cent. on an average, as compared with the organic matter in the raw material. To reduce the organic matter of the settled sewage to a point where it will not putrify in the water courses, it is estimated that there would be required one acre of sprinkling filters for 12,500 population.

These sprinkling filters, as I have already stated, would be large beds of stone, of a size ranging from one to three inches in diameter, about six feet deep. To these filters, the settled sewage would be applied from a series of sprinkler nozzles, spaced roughly ten feet apart. The sewage would then be thrown as a form of spray such as from a lawn sprinkler over the surface of the bed of stone. These sprinkler filters operated at this rate will produce an effluent which will not putrify after there has been removed from it some suspended matters which are released from the bed in an irregular way.

To clarify this filtered sewage, these projects provide for secondary settling tanks holding about one hour's flow, and of about the same size structure as the primary settling tanks, but of one-half size for a given sewage volume.

This sewage sludge would be similarly strained on sludge beds to remove the water, so as to get it in a spadeable condition for removal to a sludge bank, or any other convenient way of disposal. The sludge has somewhat limited value for fertilizing purposes, and in some cases in Europe it is taken away free of charge by the farmers of the neighborhood.

I have assumed that it would cost some 50 cents a yard

to get rid of this sludge, and that it would not be feasible to dispose of it to farmers.

Wherever the dry weather flow of sewage is subjected to filtration the sterilization process would be applied to the effluent after it leaves the filters, and not to the settled sewage before it reaches the filters. In the West Side Project where filters would not be needed with the present assumed volume of lake flow, the sterilization process would be applied of course to the flow from the primary settling tanks.

In the matter of sufficiency of sprinklers, I would say that they will reduce the organic matter in the sewage some 70 per cent. or more, and in connection with the oxygen present in the filtered sewage, they will produce a stable liquid which will not putrify upon exposure to sunlight and the air, for a long term. There are times when these beds unload their solid matter, when perhaps that would not be literally true; but generally speaking these beds, in practice at the rate here indicated would produce a liquid which would not give trouble from putrifaction.

The removal of bacteria by the sprinkling filters would probably range from 80 to 90 per cent. The liquid would be substantially free of suspended matter. The sterilization of the filtered sewage would have for its purpose, of course, the destruction of disease germs to the extent of the 10 or 20 per cent remaining in the filtered sewage as compored with that appearing in the raw sewage.

As to storm water flows, the liquid coming from the streets contains a good deal of organic matter, and would probably call for as much as 70 pounds of liquid chlorine to the million gallons. For the ordinary settled sewage coming from the primary tanks, I assume it would take some 50 pounds of liquid chlorine to a million gallons. For the filtered and settled sewage I have assumed that about 10 pounds per million gallons would be sufficient.

As to what sterilization will accomplish in point of removal of disease germs, I should say that the removal would amount to 95 to 99 per cent., depending upon the success with which the applied quantity of liquid chlorine was adjusted to the particular organic content of the liquids flowing, and recognizing the variation in such flow, and in their strength from time to time.

In the matter of pumping stations, these projects for the treatment of the sewage would involve the operation of the present pumping stations for sewage flows at 39th street,

Lawrence avenue, 95th street and elsewhere. They would also require some intermediate pumping along the line of the interceptors, at settling basins and at each of the respective filter plants it would be necessary to lift all the flow, in order to produce a head sufficient to distribute the sewage to these various sprinklers scattered over the surface of the filter bed. There would have to be a head at the nozzle of some six to eight feet, as well as to lift the sewage up to the elevation of the nozzle itself.

In regard to the question of odors and nuisances, I have already spoken of the great importance of preventing such conditions as have arisen at Columbus and Baltimore, where the sewage has become highly putrifactive before it reached the treatment works. That would be accomplished by the aeration that I have described.

In regard to the sprinkling filter sites, I have outlined certain locations which have been used as the basis of these studies. It is not necessary to treat them precisely at the areas indicated on this map marked Fuller Exhibit 1, but those approximate areas, however, are convenient and suitable; and in these instances are entirely reliable for the purposes at hand. These different filtering site areas cannot be limited to the immediate ground which would be occupied by the structures. It is found that in these beds there will grow flies and various forms of animal life, and it is necessary for that reason to purchase land which would keep other property owners from living immediately adjacent to the beds.

There is also the item of odor, which is not very serious if the sewage is kept in this fresh condition that I have spoken about with respect to aeration.

For instance at Reading, Pennsylvania, where the sewage is fresh, it is a mountainous town and high velocities obtained in all cases, the odors are rarely if ever noticed more than 300 feet away. Most sprinkling filters, however, are apt to develop an odor, in the case of large plants for a quarter of a mile; occasionally in some plants it is extended much further than this.

In these estimates made in developing this project, allowance is made for the purchase of land one-quarter of a mile in extent around the entire outer periphery or building line of the proposed works.

In regard to the question of odor around the settling basins, I do not believe that there would be anything serious encountered there, nor would the flow of storm water treated with liquid chlorine be objectionable in the water courses. It is

conceivable, however, that lack of care might produce an excessive application that might not be present except for a very short time.

That, I believe, covers in outline the main features of the best methods now available for building treatment works to clarify sewage, to eliminate the stranding of sewage solids, and putrifaction of mud banks, to take the sewage after settlement and where there would not be water available for oxidizing it by dilution, then subjecting it to the oxidization in sprinkling filters and finally in sterilizing all of these flows so as to destroy objectionable bacteria to the extent of say 95 to 99 per cent. of those contained in the original sewage.

This residual small percentage, as I have already explained, cannot be reached by sterilization or any other process, on account of some of those germs being located within the interior of tiny little particles of fecal matter, where the chemicals will not have access. These treatment works are the best than can be applied to problems of this kind, as the art of sewage treatment is known to-day, both in point of theory and practice.

In regard to the pumping stations, I might add a word and say that they are all assumed to be centrifugal pumps, steam driven, and are assumed in the estimates to be strictly in line with the installations of sewage pumping machinery in the district here in Chicago, and in other large cities. The equipment, as I have said, provides for handling the sewage at a number of points along these interceptors, and in pumping all of the sewage going onto the sprinklers.

Q. Why do you assume a population that would exist in 1920, for the Sanitary District of Chicago in making your calculations and in solving the problems?

A. That approximate figure in 1920, has shaped itself in these estimates by virtue of the fact that the population then existing in the city and in the outlying areas within the Sanitary District would roughly equal the diluting capacity of a 10,000 seconds feet flow of lake water down the main channel. It also represents the best judgment of those familiar with the details, according to my information, of the past growth and the increments in growth leading to proper and reasonable conclusions as to what the 1920 population may be.

My own purpose was largely in getting at a figure as to scope of project which would allow a comparison to be made of the treatment works for a 3,000,000 population which has come into this project, and my reflections in connection with the 10,000 seconds foot flow, when treating the population

at the legal minimum dilution ratio of 3.33 seconds feet per thousand.

Q. Then, as I understand, Mr. Fuller, you have used this figure or calculation of 1920 as a basis on which you calculate the estimates for the solution of this problem?

A. Yes.

Q. Taking into consideration the efficiency of these methods, and then putting them into operation, and taking the water supply of Chicago, how would they compare with the efficiency of the present method that is in use, in the protection of the water supply?

A. They would not protect the water supply so reliably or completely as would the diversion of the sewage of the district down the main channel.

Q. Have you made any estimates of the cost of installing and operating each of these two projects A and B, which you have mentioned?

A. Yes.

Q. Will you state how you have arrived at the cost, and what your estimates are of such cost?

A. You mean construction cost now, or the operating, or both?

Q. Both cost of installing and cost of operation.

A. I have estimated that it would cost for construction purposes to build project A, $71,365,866. The annual operating expense and depreciation I estimated at $5,116,057. I have capitalized this annual charge for operation, maintenance and depreciation at 4.25 per cent., and have added it to the investment cost. This makes a sum of $191,742,866. That is the sum which it would cost this district to take care of the sewage by project A, for the population estimated to exist in 1920, roughly 3,000,000 of people.

For project B, the investment cost I place at $131,229,707. The annual cost of operation, maintenance and depreciation, I place at $4,524,952. Capitalizing the latter sum at 4.25 per cent., and adding it to the investment cost, there is obtained $226,970,647, as representing the cost to the district of treatment works for 3,000,000 people by project B.

Q. Have you made any estimate of the cost of these same works if applied to a population which would be served by the works of the Sanitary District, in the event 12,000 cubic feet and 14,000 cubic feet of water per second passed through the channel?

A. I have assumed that the same per capita cost would

obtain, and I have pro rated the expense to get at figures for the 12,000 and 14,000 feet respectively.

Q. Will you state what the cost would be under those two projects?

A. You mean the aggregate cost?

Q. Yes, cost of installing and cost of operation.

A. Under project A, to provide treatment works corresponding to a population which would be taken care of by a lake flow of 12,000 seconds feet, the investment cost would be $85,000,000. The annual operating maintenance and depreciation cost would be $6,102,000. Capitalizing the annual cost and adding it to the investment, there would be obtained $230,000,000. The corresponding figures for treatment works of a capacity equal to that which would be taken care of by 14,000 seconds feet flow of lake water would mean, by project A, an investment cost of $100,000,000, an annual operation, maintenance and depreciation item of $7,260,000. The sum of the investment and capitalized operating expense would be $268,000,000.

I should state that these figures which I am reading are round figures, obtained with a slide rule. They are not figured to individual dollars and cents.

By project B, the investment cost of treatment works, with separate sewers to provide for a population equal to that which would be taken care of by 12,000 seconds feet flow of lake water would be $157,000,000. The annual cost would be $5,400,000. Capitalizing the operating expense and adding it to investment, the total cost becomes $270,000,000.

The corresponding figures by project B, for treatment works equivalent in population served to that for 14,000 seconds feet flow of lake water becomes for investment cost $183,000,000; the annual cost would be $6,300,000. The sum of the investment plus capitalized annual charges would become $316,000,000.

I should perhaps state with regard to project B, one or two points that I think I briefly touched upon in my preceding answer; and that is this project B deals with no storm water sewage at all, no street wash, but assumes a complete new system of sanitary sewers which would deliver to settling basins the sanitary wastes of the community. That settled sewage would pass through interceptors with aerating arrangements onto sprinkling filters, all in substantially the same way as in connection with project A. The intercepting sewers, however, would be of about half size. The pumping stations would be somewhat smaller. There would be no steril-

ization of storm flows; it would go directly into the river without treatment through the existing sewers. The settled sewage, filtered sewage, would be sterilized.

Q. When you speak of the sanitary sewers, what sewage would they collect, would that be just the domestic sewage coming from the houses and buildings?

A. And office buildings and industrial establishments, but not to any extent have I dealt with the large element of trade wastes of this community, as found in the stockyards district and along the industrial establishments on either side of the north branch. It is domestic sewage and sewage of the loop district, that is the typical sewage, which they would treat.

Q. How long would it take to install these different works that you have mentioned under projects A and B?

A. I should say that eight years would be a fair estimate for the period of active construction. I have placed the time at ten years, assuming that conditions would be favorable in all respects with regard to securing funds with which to build these works, and to get the necessary legislation, enabling acts, and condemnations of lands and rights of way.

Q. You refer to the condemnation of land, you mean for the sites where these works would be placed in the city?

A. Yes. In this period of two years, that is the difference between the eight years and the ten years, there would of course be a large amount of work involved in the matter of preparing plans and specifications for these various works to be placed under contract.

I have assumed that the amount of engineering required would always be provided without delay, and not recognizing the limitations of any staff, which usually has to be adjusted to certain regulations. That is I have assumed that any one of these projects would have a certain designing period, and that there would be as many multiples of designing forces as needed, in order to design the works in the aggregate.

In this general connection, I might state that experience shows that the minimum periods of designing and building sewage treatment works do not aggregate by any means the periods which experience has shown to have been needed in solving large problems of this sort elsewhere.

I could point out for instance that at Providence it was determined in 1887, to build chemical precipitation works, but they were not put in service until 1901. That period in the

interim was required for financing and building the necessary intercepting sewers and treatment works and in adjusting delivery of sewage to those new structures.

In Boston, the original main drainage works were recommended in 1875 for collecting the sewage of the old city of Boston and delivering it to Moon Island for discharge on the outgoing tide. Those works went into service in about 1884.

The Washington works for intercepting the sewage of Washington City and pumping it after some screening into the Potomac River below Washington were recommended by the Commission appointed by President Harrison in 1889. Those recommendations by the Commission were made in the early part of 1890. I think it was 1908 before those works were completed and put in service.

In the Passaic Valley project, in New Jersey, opposite New York City, the first recommendations there were made in 1897. The matter was reviewed by a State Sewage Commission again in 1901. There was an enabling act passed in 1903. It was in litigation in point of constitutionality until 1907, and the project in its present form was outlined by Hering & Fuller, in 1908, and the construction work was started in 1912, about a year ago, and it is still subject to injunction suits and various vicissitudes of litigation, and including an injunction suit brought in the United States Supreme Court by the State of New York with respect to discharging this sewage into the upper New York Bay.

The Charles River Dam project in Boston was active in my days there in 1891. That relates to building a dam across the Charles River near the old Cragie bridge, and preventing the exposure of the tidal flats on the Boston and Cambridge sides of the river, and in building intercepting sewers along the water front on each side to send the sewage down to points beyond or outside of Boston Harbor.

Those works were the subject of many legislative investigations, particularly a very exhaustive one made by Mr. John R. Freeman in 1903. The works have been in service I should say about three or four years, so that I think experience very abundantly shows that actual periods required for getting legislation and in getting financial programs adjusted, getting works that will not be made the subject of too many legislative inquiries and investigations by Citizens' Committees, I think all of those things taken into account make the period very much longer than the actual designing and construction calls for.

Q. How do those projects that you have mentioned compare in size with these projects here that you have outlined, A and B?

A. They are all very much smaller. I doubt whether any of them exceeds $15,000,000 in investment as compared with $70,000,000 here for project A, and $130,000,000 for project B.

Mr. Hopkins: I move that all this testimony about other peoples' difficulties be stricken out.

Mr. Adcock: Q. Will you continue your answer to the next to the last question?

A. In regard to getting sites for sewage treatment works, I have had considerable experience with a good many fairly sizable undertakings, and I know that there are a great many delays incident to taking title to lands for sewage treatment works.

I have been engaged for some seven years in what is known as the Plainfield district of New Jersey.

Mr. Hopkins: I object to the witness testifying to these matters, as he is not qualified to speak with reference to the condemnation laws of the various states.

The Witness (continuing): I think that I have designed for those communities three or four different sewage treatment works fitted to as many different sites. The project is not yet under construction, and what its future interruptions and delays may be, I do not know. I know that in the majority of instances, unless sewage treatment works are located in areas far removed from built-up areas that there is a decided objection on the part of property owners to having works so located.

I recently encountered that, in connection with a large trunk sewer project immediately north of New York City, discharging the sewage of the Bronx Valley into the Hudson River, just north of New York City line. Those injunction suits seem to be a factor which has to be reckoned with most carefully. No one can foretell what their exact significance may be in making a program in point of dates for carrying out these large sewage treatment projects.

Q. The projects that you have described, A and B, do they involve the tearing up of the streets of the city in any particular, or to any extent?

A. Project A, would involve tearing up streets along the lines shown here in red ink on this map marked Fuller Exhibit 1. It would cover a good many miles of streets in the vicinity of the water courses of the north branch, the main

Chicago River from 39th street over beyond the stockyards district, to a point where 39th street meets the Drainage Canal; also down through the Calumet district as shown in this plan.

In project B, there would be involved the tearing up of every street throughout the district, in order to build the sanitary sewers in it to parallel the existing sewers. It would not only mean tearing up every street that is now paved, but it would also mean lateral house branches from the street sewer out to the curb line under the sidewalk to the property to the building line.

It would encounter, of course, a good many underground obstructions, in the nature of interference by existing utilities, water mains, gas mains, electric light conduits and telephone conduits, etc.; also make a decided impression on street pavements; involve considerable care in maintaining trolley lines in service during construction periods.

Q. Now, Mr. Fuller, you have stated what you consider to be the cost of installing projects A and B, and also the annual cost of operation of projects A and B, each respectively. Will you state how you have arrived at the cost of installation, the cost of operation and the elements which you have taken into consideration in arriving at such costs?

A. Taking up first project A, the intercepting sewers are assumed to be of a capacity of 900 gallons per capita for the 1930 population. These intercepting sewers are built of concrete, in open cut to a depth of some 30 feet.

These intercepting sewers are assumed to have a velocity of not less than 2.5 feet per second; and where the conditions permit, a velocity as high as four feet per second.

The construction cost per running foot of the sewers of the sizes required are taken from the records of the district, showing their actual experiences in construction cost of sewers of the respective sizes, adjusted to the prices of current date for labor and materials.

The sewers are predicated upon excavation being made by machine in all streets that are sufficiently unobstructed by the utilities of other than a sewerage nature. On the streets that are congested with various underground obstructions, the excavation is assumed to be made by hand.

In regard to the pumping stations, they are all assumed to be steam driven pumps and the unit price is uniformly taken at $500, per water horse power for the lifts involved.

The aerating devices are assumed to cost $1,500 per mill on gallons of sewage to be aerated.

The cost of sedimentation tanks with their various appurtenances is taken at $2.40 per capita for the population connected with the sewers leading to these settling tanks. This item of $2.40 per capita is sub-divided into the following:

Venturi meter, four cents.

Grit chambers in which to remove the heavy matters coming from the street wash, 15 cents.

Sedimentation tanks of one story Imhoff type, $1.93.

Sludge beds, 18 cents.

Laboratory and miscellaneous appurtenances, 10 cents.

Total, $2.40 per capita.

The sprinkling filters are assumed to cost, with their final settling tanks and appurtenances, $5.20 per capita. This item is divided as follows:

Dosing tank and piping for applying the sewage to the filters, 20 cents.

Sprinkling filters, $3.80.

Final tank for settling, $1.00.

Sludge beds for final tanks, 10 cents.

Laboratory and miscellaneous items, 10 cents.

The sterilization devices dealing with the storm flows are estimated at a cost of $8,400 for each square mile of area tributary to the treatment plant. This is on the basis of $210 per million gallons, with an assumed maximum run-off of 40,000,000 gallons per day per square mile. Under these conditions, there would be a storage tank in which the storm flows would be retained under conditions of maximum flow for about 10 minutes.

I have applied in every instance to the sums obtained by multiplying the unit prices above given by the number of population as the case may be tributary to each plant, certain allowances for overhead, and for interest during construction.

To the figures for unit prices above given, I have added to the resulting sums an item of 25 per cent. to cover overhead cost, including engineering, legal expenses, administration, clerical work, omissions and contingencies such as are bound to arise in preliminary estimates of projects of this nature. I have also added interest during construction. By that I mean that where it would take eight years to build plants for the treatment works of this district, I have assumed, as is quite generally the rule in appraisement matters, in getting at the value of completed structures, interest at the ordinary rate, here taken at 4.25 per cent. on the full amount of construction work for one-half of the period estimated to

be required for construction. In the case of land, I have taken figures from the officials of the district who have looked into these matters in detail.

I believe I have already stated that in connection with sprinkling filters, an area is taken equal to a quarter of a mile in width around all sides of the treatment works. That would mean, for instance, the Lawrence avenue project about 630 acres; the West Side project, 720 acres; the 39th street project, 650 acres; the main project in the Calumet District, 364 acres.

I have personally visited the areas considered as sites for the filtering projects and have been in general over the location of the various structures involved in these treatment works. I think the sites are proper ones and as good as can be selected.

The estimated cost of this land, as I have already stated, is a matter concerning which I am not personally informed, but have taken that from the officials of the district. In regard to the treatment works themselves, I should state that the pumping stations, settling basins, filters, sterilizing devices are all estimated by me upon individual studies predicated upon quantities of the different structural work involved and based upon my personal experience at various places in this country, such as Reading, Columbus, Atlanta, Schenectady, where sprinkling works now exist, and upon the most modern settling basins of the two-story Imhoff type, such as built at Atlanta and elsewhere. These studies are predicated further upon drawings which I have prepared, endeavoring for these large projects to make the structures as economical as possible.

In my judgment, these various treatment works are predicated upon unit prices for excavation, concrete and other work as low as is consistent with the local market conditions for labor and materials, and upon structures as economically laid out as is feasible.

The pumping stations, as I have already said, are estimated to have cost $500 per water horse power, and that estimate is predicated upon a personal study of the actual cost of similar sewage pumping stations in this district, and other large American cities.

The interceptors and the aerators have been discussed fully by me with the officials of the district, and I believe that as the result of those conferences the unit prices and the structures involved are thoroughly fair and reasonable for the work which they would do, and which work is as small an amount

as is consistent with the nature and the scope of the problem.

To the estimate which I have prepared for project A, I have added, as already stated, 25 per cent. overhead and an interest charge of 34 per cent. on the land for the period of eight years, that is, 34 per cent. interest. On all construction work, I have added an interest item of 17 per cent., equal to the interest for four years on the whole construction work, or one-half of the estimated period of construction.

The different portions of these treatment plants under project A, with their respective amounts, including overhead and interest are as follows:

Interceptors, $16,669,974.

Aerators, $2,014,593.

Pumping stations, $12,383,718.

Settling basins, $10,895,157.

Sprinkling filters and appurtenances, $16,233,138.

Sterlizing devices, $2,393,073.

Land, $5,190,322.

Utilities, meaning by that the various pipes, conduits and underground obstructions for other public service, $5,585,-891.

That gives the total of $71,365,866.

I should state with regard to the allowance for public utilities, in the nature of what it would cost to move water mains, gas pipes, telephone conduits, electric light conduits and the like, that I have examined carefully the figures which have been obtained by the officers of the district, in conference with the various people in charge of those utilities. I have looked them over, and made comparison with what my experience has been in connection with similar work elsewhere, and I consider those allowances, those estimates fair and reasonable.

Now, with respect to the annual cost of operation, maintenance and depreciation for project A, first, as to depreciation I have made allowances as follows:

Interceptors, .5 per cent. per annum, that is depreciation.

Aeration devices, 3 per cent.

Pumping stations and equipment, 3 per cent.

Settling basins, 1 per cent.

Filters and appurtenances, 1 per cent.

Sterlizing devices, 3 per cent.

Land, nothing.

Utilities going with the interceptors, .5 per cent.

That makes an annual sum for depreciation or obsolescence of $886,297.

The pumping station operation, maintenance, repairs and

renewals I have estimated at $350 per water horse power per year, equal to four cents per water horse power hour, or 16 cents per million gallons lifted one foot high. That is based upon a careful study of the operation of sewage pumping stations in this district, and in the case of other large sewage pumping stations in other American cities.

That gives an allowance per year for pumping stations of 6,544 water horse power, $2,325,400.

The cost of operating the aerators is taken at eight cents per capita based upon the one-tenth cubic foot of air pumped into each gallon of sewage, as I have previously explained, and that amounts to $166,280 per annum.

In regard to the settling basins, I have estimated the cost of handling the settling basins with the grit chambers, which would precede the settling basins and take out some of the coarse street wash at 18 cents per capita. That sum allows, as I have previously stated, an estimate of 50 cents per cubic yard for removing and disposing of the spadeable sludge. I should make it plain that in my judgment there is no likelihood at all of any substantial quantity of this sludge being used for farming purposes such as I have mentioned before as being experienced to a limited extent in some of the small German cities.

For these large projects, I am convinced it would be necessary to dispose of the sludge in other ways than relying upon the efforts of farmers to take it away.

This operation of settling basins, in point of attendants, supervision, is predicated upon actual experience in operating plants of this sort elsewhere. The cost of operating the settling basins per year amounts to $558,720. Filter operation is estimated at 12 cents per capita per annum, giving the aggregate figure of $256,140. These estimates are made on the assumption that they would include a reasonable average allowance for repairs and renewals, to keep them working in good shape.

In regard to the filters, I should make it plain that I have not in this project A assumed that there would be such filters built for the West Side district, on the assumption that the sewage of the loop district and the West Side district, after sedimentation, would be sent into the channel and the lake water flow of 4,167 seconds feet would oxygenate that settled sewage so as to do away with the need for filtration.

To make that point clearer, I should state that the settling basins estimate of cost for maintenance applied to the 3,104,000 people, and the filter cost applied to 2,134,500.

As I have explained previously, this loop district and the West Side district are assumed also to carry on the sewage end the flow of a floating population that is not resident here of 300,000 people on an average.

Coming now to sterilization, I have assumed from my experience elsewhere that for the final filtered sewage it would require ten pounds of liquid chlorine per million gallons; for plain, settled but unfiltered sewage, 50 pounds per million gallons; of storm water overflow 70 pounds per million gallons. The cost of this liquid chlorine I have taken at a current market price of ten cents per pound. This would give an aggregate annual cost for sterilization of $885,820.

I further assume that there would be four superintendents in charge of the four main sewage treatment projects; that their annual salary, $3,600, gives $14,400 for general superintendence.

There was an item also of maintenance of intercepting sewers, taken roughly at $500 per mile of interceptors per annum, including the general outside management expenses, and predicated upon experiences on similar work elsewhere, amounting to $23,000 per annum.

That gives a total annual cost of operating of treatment works by project A of $5,116,057, the figure which I previously stated.

Q. Those figures are based upon an estimated population of approximately 3,000,000 people?

A. Yes, in round numbers.

Now, I will go to project B. Taking up now project B, which involves duplicating the present sewer system or paralleling it with a new system of sanitary sewers, which would take household wastes only, I find that the records of the City of Chicago show that there are now in existence 2,037 miles of sewers. The cost is given as $31,867,268. These are the sewers exclusive of the large interceptors along the lake shore. This figure gives roughly a cost of $15,800 per mile.

As I have stated already, these present sewers, with the exception of here and there some limited areas that have recently been annexed, are all built upon the combined plan of receiving household wastes and also the storm water. They were built at a time when the public utility item of underground obstructions and pavements was very much less of a factor than at the present time. The new system of sanitary sewers involved by project B, would be smaller in size, but they would involve cutting the pavements, replacing the pave-

ments and taking care of the public utility underground obstructions, so that I am inclined to be lieve that their cost would equal that of building the old sewers under the conditions which existed at the time when they were actually constructed. I have looked into this matter in connection with two or three sewerage system appraisals that I have been on during the past year, and I find that $15,000 per mile of sewers on an average, taking into account the pavement and public utility obstructions underground is a reasonable price. In fact it has been exceeded in a number of cities elsewhere, for instance at New Orleans, where I have been connected with the complete new system built for that city within the past ten years. The construction of the sanitary sewers in the streets, estimated by me to cost $30,000,000, in round numbers will not tell the whole story by any means. There would still be required connections between the street sewers and the 300,000 properties, by that meaning houses, business blocks, etc. Not only would there have to be built the house connection for each of these 300,000 properties from the building to the street sewer, but there also would have to be rearranged the plumbing facilities within the house, disconnecting them from the present storm water sewers and reconnecting them to a new house lateral. Storm water coming from roofs would also require separation so that it would go to the old and not to the new sewers. Taking into account experiences elsewhere, in connection with the resewering of a city, I estimate that it would cost on an average $100 per connection for each of these properties, making for the entire district $30,000,000, which added to the cost of the new street sewers makes a total of $60,000,000. In arriving at the total investment because of project B, $131,229,707, I started out with the investment cost of project A, of $71,365,866. To that I have added the $60,000,000 for separate street sewers and the house connections and plumbing rearrangements. I have also added the cost of building sterilizing devices for the flow of these separate sewers alone. That amounts to $136,159, the sum of which three items is the aggregate figure of $131,229,707 above stated.

From this I have deducted the cost of building storm water sterilizing devices as outlined in Project A, that sum being $2,393,073. I have also estimated that the cost of interceptors and pumping stations would be less by Project B, than by Project A. I have considered these two items, and taken the cost of the interceptors at one-half of what it would be in

Project A, or $8,334,987, as an item to be deducted. Adding together these two items for deduction, storm water sterilization and reduced size of interceptors, with allowance for pumping station reduction, there is obtained $120,501,647, as the investment cost for Project B.

The net cost of operating Project B, amounts to $4,524,952 per annum. That is made up in my estimates of the operating cost of Project A, namely $5,160,057. To that I have added a depreciation of ½ of 1 per cent. per annum on the $60,000,000 investment for the separate system of sewers, namely $300,000. I have also added the cost of maintaining the sanitary sewers estimated from my experience elsewhere at $40 per annum for 2,000 miles, or $80,000. The sterilization of the sewage flow I have taken at $679,500. That gives a total of $6,175,557. From this sum I have deducted certain items which would not be involved by this Project B, which were taken into account by Project A. These involved the depreciation on the sterilization for storm flow devices for the interceptors of a total expense as compared with those for Project B, and the actual cost of sterilization of storm water flows.

I have also assumed that the pumping station cost would be 4/5ths of that involved by Project A.

I have also assumed that the volume of sludge to be removed would be less. This is on account of Project B, not involving the street wash. In this item of sludge removal for Project B, I have assumed to cost 6 cents per capita per annum less than for Project A. This gives credits to Project B, of $1,650,605; the individual items amounting as follows:

Depreciation on sterilization devices, $71,790.

Depreciation on one-half cost of interceptors, $41,675.

Sterilization cost, $885,820.

Credit of one-fifth pumping station operating expense $465,080.

Reduced item of sludge disposal $186,240.

Subtracting these credits from the above summation of the operating expense for Project A, and the new items involved by Project B, there is obtained the net sum above stated, namely $4,524,952.

Q. This unit prices that you have mentioned in connection with the operation and installation, on what are they based?

A. So far as the treatment works are concerned, they are based upon my individual study of the experiences ob-

tained in building and operating sewage disposal devices in various places in this country and in Europe, where I have made an individual study of these matters. They were produced in my office in connection with quite thorough studies of the amount of construction work involved, keeping the size and design of these tanks and filters at a minimum of expense for accomplishing the work which I have described them to be able to accomplish.

Q. Is that true also of the items which you have mentioned there as making up the sum of the cost of operation?

A. The operating expenses for the treatment works themselves are also the result of my individual study of these matters, based upon my experience at various places in this country and elsewhere. In regard to pumping stations, I should say also that the cost, both for construction and operation represent my individual experience in studying these matters as actually has been encountered in handling problems of this type, in various places in this country and abroad.

Q. You have mentioned an item there that you assumed as the overhead, cost of legal expense, contingencies, engineering and so forth. Upon what was that estimate based?

A. That is based upon my general experience in connection with projects of this kind of a very diversified nature, complex type of structures, the uncertainty under which they are found in all preliminary stages. It is based upon the practice in New York in connection with handling large projects even of a similar nature with this. There are always things that cannot be foreseen. The contingent item is a large factor in projects of this magnitude even where in disjointed studies they have received very careful consideration; and experience in handling these large enterprises shows that the amount of money paid to a contractor for building certain projects, plus the cost of engineering expense, plus the ordinary legal and administration expense, still falls short of the aggregate cost to the community. And I think experience in large enterprises elsewhere clearly shows this is correct, that the overhead allowance of 25 per cent. is fair and reasonable.

Adjourned to Tuesday, November 18, 1913, 10:00 A. M.

Tuesday, November 18, 10:00 A. M.

Met pursuant to adjournment.
Present same as before.

GEORGE W. FULLER resumed the stand and testified further as follows:

Mr. Adcock: Q. You have spoken of sprinkling filters and you provided in your Projects A and B, for the construction of sprinkling filters. Will you state why you have used sprinkling filters in the plans for these two projects?

A. These two projects for remedial measures, where there would be an insufficient volume of lake water for oxidizing the sewage, provide for sprinkling filters to make the sewage non-putrescible by oxidation, which would take place in those beds. These sprinkling filters for large projects are uniformly used, because they are the most efficient and economical means available. There is for some small suburban communities a different type of filter called contact beds, found in some instances. Those contact beds are so much more expensive that they are not used at all for large projects.

Sand filters of the intermittent type are clearly more expensive and not available here, because porous sand is not to be found.

Now returning to the sprinkling filter question I should say very clearly that that is the type of artificial oxidizing means taken at Columbus, Atlanta, Reading, Baltimore, and in all of the large projects figured upon in the last six or eight years in America for oxidizing sewage where the dilution method is not available.

Sprinkling filters are also found in nearly all of the large filter plants in Europe where oxidation of the sewage must be secured.

It is important to note that at Birmingham, England, this is the type of filter which has succeeded the use of sewage farms.

At Paris this is the type of filter adopted for the various suburban communities lying south of the city, and the city of Paris itself began some two years ago to install filters of this type to take the place of the sewage farms now becoming inadequate.

At Berlin, at Wilmersdorf, the sewage of the various south-

ern suburbs of Berlin is treated on a sprinkling filter plant, designed ultimately to serve about 1,000,000 population.

Without any doubt at all the sprinkling filter is the best means of oxidizing sewage in works of artificial construction where the dilution method is not available.

I think I have made it plain that these sprinkling filters would have applied to the sewage after it had been passed through settling tanks, in order to remove the relatively coarse solid matters. That is quite important, in order to be able to distribute the sewage over the surface of the sprinkling filters through the series of nozzles which have to be of a diameter of perhaps half an inch or less, in order to throw the sewage as a spray over the filter surface. If the solid matters in sewage were not removed, it would involve an enormous expense in attempts to keep these sprinkler nozzles free from clogging, and in fact it would be impossible to make the filters work well, even with an indefinite or theoretically unlimited amount of operators, the uniform distribution of the sewage over the sprinkling filters being one of the fundamental features to be secured at all times, in order to obtain the results that I have spoken of, namely a non-putrescible effluent.

And furthermore, in connection with these sprinkling filters, the solid matters which seem to accumulate on the surface of the stone have to be removed before the filtered liquid reaches the stream, and this is the reason why a secondary settling tank has to be used in connection with the sprinkling filters.

Q. In the cost of operation of these works which are embraced in Projects A and B, did you include the cost of operation of the other works of the Sanitary District, those that are already constructed?

A. No, I did not. I made no allowance for those items which would be involved by the use of the dilution method through works now existing. That statement applies to the pumping stations, for instance, that are owned and operated by the city as well as the pumping stations that are operated by the District at 39th street, Lawrence avenue, Wilmette, etc.

Q. Then as I understand it the cost of the operation which you mentioned for the works embraced in Projects A and B would be in addition to the cost of operating the other works of the Sanitary District in the flow of 4,167 cubic feet per second.

A. Yes.

Q. And the same answer would apply to the cost of installation. That would be in addition to the cost that the Sanitary District has already expended?

A. Yes.

Q. Do you know what the cost of installation or construction has been for the works of the Sanitary District, or that would be necessary to divert 10,000 cubic feet of water per second, 12,000 and 14,000 cubic feet through the main drainage channel.

Mr. Adcock: I will say, in connection with this question that the figures which the witness will give are figures which have been given to him by the District; and I simply wish to have it appear in the record at this time for the purpose of answering subsequent questions. We will show by further testimony the actual cost. If we do not it may be stricken out.

Mr. Hopkins: It is a case of assuming they are correct.

Mr. Adcock: Assuming they are correct for the purpose of the examination of this witness.

A. Yes, I have been informed by the officers of the District what these costs would be.

Q. Will you state what those costs are?

A. This investment cost?

Q. Investment, and you may include in that the cost of operation.

A. The figures furnished me by the officers of the District are shown in the following table:

Flow C.F.P.S.	Investment.	Annual Oprg. and Depr.	Capitalized Gross.	Electrical Credit Capitalized.	Net Capitalized.
10,000	$64,095,082	$508,832	$76,067,600	$13,242,000	$62,825,600
12,000	78,385,182	728,105	95,517,070	17,790,000	77,720,070
14,000	84,020,182	786,238	102,519,910	22,306,000	80,213,900

Q. In your consideration of sewage treatment works through the Calumet area other than by dilution, how do your estimates and proposed procedures at the present time compare with those that you reported upon in 1906 to the International Waterways Commission, and if any difference exists state briefly the reasons for the same?

A. In 1906 I prepared a report for the International Waterways Commission, in conjunction with my former partner Mr. Hering. In that report there are quite a number of

conditions assumed that are of a considerable influence in showing differences between estimates of that report and that which I have testified to in this suit.

In the first place, in 1906, we were figuring upon a population of 1,200,000 people for the Calumet District. That figure came in as a result of getting for treatment works an amount of work done equal to that which should be secured with a flow of 4,000 seconds feet, as then discussed and proposed for the Calumet Sag Channel, and on the basis of the legal minimum rate of dilution.

The figures of 1906 were also made upon the assumption that that area, with its relatively sparse population, could be best sewered by building sewers on a separate system. By that I mean that it was assumed in 1906 that the comparatively few sewers in that area could be best devoted to handling storm water, and all household and ordinary wastes, from office and business buildings and some minor industrial wastes, would go through an entirely new system of separate sewers. Those separate sewers, however, were not dealt with at all in the estimates presented to the International Waterways Commission. Those estimates started out on the assumption of intercepting sewers dealing with sanitary wastes only, and equal to 150 gallons per capita daily.

The 1913 estimates deal with 300 gallons per capita for dry weather flow, or flow at times other than excessive rainfall. The amount of storm flow would add about 10 per cent. to the average volume of liquid treated per capita. This made a marked difference in the cost of intercepting sewers, dealing in 1907, with 150 gallons for 1,200,000, and at the rate of 900 gallons per capita for a population in 1930, which would be for this district 301,000. In consequence of these differences in assumption as to population, type of sewerage system, capacity of interceptors, the investment estimated in 1906 was $3,795,000 for a population estimated at 1,200,000. The figures in 1913 became $2,557,240, for a population of 301,000. These latter figures, I should state, include, however, not only the intercepting sewers but the pumping stations.

In 1906, no provision was made for the aeration of the sewage as it flowed along the interceptors. That is included in 1913, owing to the fact that experience at numerous places elsewhere has shown the urgent importance of keeping the sewage applied to treatment works from getting into a putrifying condition before applied to sprinkling filters.

As regards land, there was no direct allowance made in 1906, but in 1913, the allowance is $697,750.

Coming to the treatment works themselves, the preliminary settling tanks are on a distinctly different type. In 1906, it was figured that they would install so-called single story septic tanks which on account of their objectionable odors for sizable projects are no longer in vogue. Their cost for building simple storage tanks holding eight hours' flow would have amounted to about 91 cents per capita for the assumed population of 1,250,000.

In 1913, estimates had been made on the basis of two story tanks of the Imhoff type, with arrangements for septicizing the sludge in a compartment entirely and distinctly separated from the upper or settling compartment. The relative sizes are of course increased by virtue of the fact that the 1906 estimates provided only for 150 gallons per capita, whereas in 1913, the corresponding figure is 900 gallons. The investment cost per capita in the 1913 estimates is $3, as compared with 91 cents in the estimates of seven years ago.

Those differences are clearly explained by the advances in the art of sewage treatment, as I have previously explained at some length.

In regard to sprinkling filters on the final settling tanks, the investment is markedly increased. In the 1913 estimates it is $6.50 per capita as compared with $3.64 in 1906. The increase is explained partly by there being now assumed a load of 12,500 people per acre of sprinkling filters as compared with 15,000 people in 1906. The main difference, however, is explained by more complete and adequate structures, arranged first to distribute the sewage more effectively over the surface of the sprinkling beds, and secondly in providing settling tanks of the two story type so as to guard against at intervals the belching forth of sludge into the waterways, as takes place at numerous places elsewhere, where single story settling tanks are used.

There is also in the 1913 estimates an allowance of some $399,000 estimated to be required for treating by sterilizing processes all of the sewage which goes through the settling tanks and sprinkling filters up to a volume equal to 900 gallons per capita. And furthermore the excess storm flows are likewise estimated now to be subjected to efficient sterilization. This adds on the investment basis an item of about $1.93 per capita for structures not considered in 1906, as they had not yet appeared in the art of sewage treatment.

Those are the principal items on the investment in the Calumet District with respect to variations in the estimates of today and of seven years ago.

I should furthermore point out that in 1906 no allowance was made for interest during construction, and the overhead percentage was taken as 15 per cent. rather than 25 per cent. Experience during intervening years has clearly shown the wisdom of the allowances made in this current estimate.

The aggregate estimates in 1906 for a population of 1,200,000 people was $9,257,500. The current estimate is $5,551,470, on the basis of the 301,000 population assumed to be that of the year 1930, as regards intercepting sewers and pumping stations, and for sewage treatment works for a population of 207,000 estimated as of 1920.

In further explanation of the relative increases in cost of sewage treatment works of today as compared with estimates of 1906, I should make reference to the increased price of labor. That I have had occasion to ascertain personally from construction work in this district, and know it to be a very substantial factor, without trying to make any analysis to show precise relative figures. To some extent that also applies to materials used in construction.

With respect to the cost of operation of sewage treatment works, the estimates of 1906 show for a population of 1,200,000 an annual sum of $419,000. The corresponding annual cost of works in 1913, to serve a population of 207,000, is $416,000. This difference is made up chiefly of two items, one of which is the pumping of a volume of flow estimated at 330 gallons per capita in 1920 population for the current estimates as against 150 gallons per capita in 1906.

In the estimates of seven years ago, no allowance was made for sterilization, and the current estimates show $38,420.

A third item of difference is the aeration, which was not figured upon at all in 1906, but which is now found to be necessary to eliminate odors, and is taken per year at $16,560.

The discrepancies are not great in regard to the other items, except that I should point out clearly that in 1906 no allowance was made for depreciation, except in the case of the sprinkling filters, whereas in the current estimates there is an allowance taken at what I have already described for the various remedial projects, namely 5/10ths of 1 per cent. per annum, for intercepting sewers, 1 per cent. for settling tanks and sprinkling filters and 3 per cent. for pumping stations, aerating devices and sterilizing equipment. The net differ-

ence of all of these items is most clearly stated by pointing out that in 1906 the annual cost was taken at 35 cents per capita per year, whereas the corresponding figure in the current estimates is $2 per capita per year. These figures take into account pumping aeration, operation of intercepting sewers, settling tanks, filters and sterilizing devices.

Q. In your estimates of 1906, where was the 1,200,000 population assumed to be?

A. In the Calumet District.

Mr. Adcock: I think that is all.

Adjourned subject to notice.

Depositions taken pursuant to stipulation of counsel for respective parties, statutory notice being duly waived, at the Belmont Hotel, New York City, on November 26, 1913, and on subsequent days.

Appearances:

Mr. James H. Wilkerson, representing the Government.
Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian, representing the Sanitary District.

GEORGE W. FULLER resumed the stand and testified further as follows:

Cross-Examination by Mr. Wilkerson.

Q. You were in partnership with Mr. Rudolph Hering, in 1906, were you, Mr. Fuller?

A. Yes.

Q. You are one of those who signed a report dated December 18, 1906, to the International Waterways Commission?

A. Yes.

Q. That is the report which was printed in the abstract of the evidence in this case, prepared by the counsel for the defendant, beginning on page 2882, and on page 313 of the abstract, is it not?

A. Yes.

Q. And it was printed as Appendix F, to the report of the International Waterways Commission dated January 4, 1907; that report having been published as War Department document number 293. Am I correct in that statement?

A. Yes.

Q. Did you prepare at any time any other report covering this subject for the International Waterways Commission?

A. No.

Q. Did you prepare at any time any report dealing with this subject for any other department of the Federal Government?

A. No.

Q. Were you examined as a witness at any hearing before the Secretary of War relating to the questions covered by the report of 1906?

A. No.

Q. Or similar questions?

A. No.

Q. Were you ever called upon to prepare any data to be submitted to the Secretary of War subsequent to the report which you made in 1906?

A. No.

Q. The first attention then which you had given to the subject since the report in which you joined with Mr. Hering in 1906 was when you commenced to prepare for your testimony in this case, during the spring of the present year?

A. Yes, that is to say February of this year I commenced my preparations for my testimony in this suit.

Q. So that, so far as you know, the only document prepared by you which has ever been submitted to the Department of War, or any other department of the Government, or any other Commission of the Government for consideration was this report of December 18, 1906?

A. Yes, that is so.

Q. What I am getting at is, that is the only thing from you which the executive officers of the Government have ever had before them for consideration in any action which they might have taken with reference to this matter?

A. Yes, that is so. That is the only report that I joined in the preparation of, or prepared myself, prior to my preparation for testifying in this suit at the present time.

Q. And none of these figures, except as you may have present original figures relating to the Calumet project, none of the figures which you have submitted in your testimony here have ever been submitted, either to the Secretary of War, or anybody connected with the War Department, or the Chief of Engineers, or any Government commission?

A. No, they have not.

Q. Were you in partnership with Mr. Hering in 1907?

A. Yes.

Q. Do you recall a report which he made for the president of the Sanitary District of Chicago, dated October 15, 1907?

A. Yes, I recall such a report, but I had nothing whatever to do with its preparation.

Q. You did not read that before it was submitted?

A. No, I did not.

Q. When was the first time your attention was directed to that report; or rather, when was the first time you ever gave it any consideration?

A. Well, I presume I might have glanced over it shortly after Mr. Hering's return from Chicago. This report, I recall distinctly, was prepared in Chicago; and it is so dated, I notice. Now, to what extent I looked it over in the Autumn of that year, shortly after its presentation, I don't recall.

Q. Did you study it in connection with the preparation of your testimony in this case, which commenced in February of this year?

A. Yes, I read it over among other papers, as one of the first things which I did in my preparation.

Q. What was the nature of the work which you did at New Orleans?

A. I was a member of a Board of Advisory Engineers, which was appointed in the spring of 1900, and continued until about 1909. That board of which I was a member had to do with the consideration of the best general methods available under local conditions for the design of a sewerage system, and also a new water supply for that city. And there were meetings from time to time of the board which passed upon the methods and designs, the details of which were prepared in the office of the Local Engineer in charge of those works. The drainage project, during the latter portion of that term of years, was also taken over by this Board of Sewerage and Water; that is it succeeded to the duties and functions of an earlier appointed Drainage Board.

Q. Has that work been completed yet?

A. Not entirely so, but the major portion of the city has been provided with a water supply from a new plant, and it is also provided with sewerage works to take care of the domestic wastes. The drainage works have been in operation, as a partially completed plant, since about 1900.

There is still under consideration and under construction extensions, I think, to all three of those municipal pro-

jects, but particularly as regards the sewerage and storm water drainage.

Q. The water supply plant has been completed, has it?

A. That is the supply end of the new water works has been completed, so far as required for quite a number of years.

Q. How much was spent on that if you know?

A. The total expenditure was roughly $20,000,000.

Q. On the water supply?

A. No.

Q. That is on both the water supply and sewerage?

A. The memoranda which I have at hand show an investment in the water supply and distribution works of, roughly, $8,800,000. The memorandum here as to sewerage takes into account both the separate system for the sanitary sewage as well as the drainage works to remove storm water.

The aggregate of drainage and sewerage works is roughly given here in this memorandum as $14,600,000; and of that sum, speaking from memory, there was spent prior to 1900, about $5,000,000 for drainage; that is for removal of storm water, independently of sanitary sewers. That last figure for drainage has been probably increased somewhat, between 1900 and the present time.

Q. But that work has not yet been completed, that is the sewage disposal works?

A. The sewage disposal is completed, but there are still being built street sewers out into the less thickly occupied areas of the city; and in particular there are being built the house connections from the street sewers to the properties.

Q. All this work which you have been describing is part of the one problem of getting and keeping a supply of pure water for the people of New Orleans. Is that the purpose

A. No, the drainage and sewerage matters are not so directly related to the water supply as in many cases. They are independent sanitary propositions.

Q. What is the chief end accomplished by the drainage and sewage part of the plant?

A. Well, it is an important part of municipal sanitation. The city is almost entirely flat, after you get away from the levees adjoining the Mississippi River, and the heavy rains in earlier years caused the water to stand for a depth of several feet for many, many hours.

The drainage works have for their purpose the removal through artificial canals of that water out into Lake Pontchar-

train. There probably is a somewhat unusual connection between those drainage works and the sanitation of the city, owing to the influence of flies in transmitting disease; but it is not connected with the water supply end of the project. The sewerage is intended to remove household wastes, fecal matters, and eliminate the use of privies in a country where the ground water level originally stood only two or three feet below the level of the surface of the ground.

Q. So both the water supply and the sewage disposal projects cost more than $20,000,000, that is the only parts that you had to do with?

A. The water supply and sewerage cost roughly $15,000,000 I should say, and my relation to the drainage works was incidental only, as regards certain extensions and changes in the system that had been put in service prior to my appointment on this Advisory Board of Engineers.

Q. I was just getting at the total cost. The total here is $23,400,000 for water supply, sewerage and drainage. Does that represent the total cost of all the works of that kind that are now in use at New Orleans?

A. I think that is substantially correct, yes.

Q. What is the population of New Orleans, if you know?

A. In 1910, the federal census showed 339,075.

Q. You have also had some connection with the Passaic Valley Trunk Sewer Project in New Jersey. Just what is that project?

A. Well, that project refers to means for eliminating sewage nuisances arising in the lower stretch of the Passaic River. This river enters Newark Bay, and in that way into upper New York Bay, and drains an area of perhaps 1,200 or 1,300 square miles. It is the river on which the Cities of Patterson and Passaic, large mill towns, are located; and below Patterson and Passaic, for the last 15 years and more, the sewage pollution has reached an excessive degree; offensive odors arose, and the stream for many months is foul smelling, black, discolored. The Passaic Valley Project involves an intercepting sewer; the trunk sewer starting in Patterson, some 20 miles or so west of New York, and in this trunk sewer it is proposed to collect the sewage of Patterson and Passaic, Newark and various suburban residential communities, and pump it from the terminus of that sewer in the Newark meadows through a channel out into the Upper New York Bay.

Q. Has that work been completed?

A. No, it was started in point of actual construction only about a year ago.

Q. What was the preliminary estimate of the cost of the project?

A. Some 12 or $13,000,000.

Q. Where do those towns get their water supply, the towns that are served by that sewage project?

A. Patterson and Passaic bring their water supply from this same river at Little Falls, a point on the Passaic about five or six miles above the City of Patterson. The City of Newark formerly obtained its water supply from the lower Passaic River, opposite the present City of Belleville, but some 20 years ago changed its source of supply to one from upland sources, whereby a gravity flow was obtained from various reservoirs built upon a tributary of the Passaic River.

Most of the residential towns obtain their supply from the same private company that takes their water from Little Falls, and supplies Patterson and Passaic, as I have previously stated.

Q. You spoke of some litigation before the Supreme Court of the United States in that project. What litigation do you refer to specifically?

A. That is an injunction suit still pending brought by the State of New York, in an effort to restrain the State of New Jersey and the Passaic Valley Sewerage Commission from discharging the sewage from this Passaic Valley sewerage district into the upper New York Bay, in the vicinity of Robbins Reef Light. That light is about three-quarters of a mile or so north of Staten Island the landing place of the Staten Island ferryboats.

Q. Your employment is by the State of New York?

A. No, I have not been employed actively in that litigation. I was employed on a number of occasions by the Attorney General's office of the State of New Jersey, in conferences, and particularly in connection with a stipulation whereby the United States Government, which had come in as an intervener, withdrew as an intervener on making certain contractual stipulations with New Jersey in point of arrangement of these drainage, sewerage works; and particularly with regard to certain clarification appliances which the Passaic Valley Commission agreed to install.

Q. You were a member of the Commission appointed by the United States Senate to consider water supply matters

in connection with the City of Washington. Have you followed that up to the extent that you have any knowledge as to the cost of works constructed in Washington, in connection with their water supply and sewage disposal?

A. I have general information about the Washington cost for water supply.

Q. How much did the water supply works there cost?

A. My memorandum shows that at Washington the water supply investment, that is for the supply works, aqueducts, filtration works, distributing system was roughly $19,500,000.

Q. And the sewage disposal works cost how much?

A. That is $15,700,000 roughly. That is the total cost for the sewerage system and intercepting sewers and disposal works.

Q. Amounting in the aggregate for water supply and sewage disposal to how much?

A. Roughly $35,300,000.

Q. And what is the population at Washington?

A. The federal census of 1910 showed 331,069.

Q. That would be about how much per capita for the combination?

A. Roughly $104 per capita.

Q. You stated that you served as Consulting Engineer to New York City, both as to the Catskill Project and the Croton water supply. Do you know what the total cost of the Croton water supply has been to the people of New York City?

A. I have no memorandum of it.

Q. I do not care for the precise figures but if you have any information on the subject which will enable you to make a general statement, I would be glad to have you do so, subject to any correction that you see fit to make.

A. Starting with the Croton Works that began to deliver water to New York City in 1842, and with the various extensions that were made up to within the last few years, I should say that roughly $50,000,000 had been spent on the present water supply of the old City of New York; that is Manhattan Island and the Bronx.

Q. What about this Catskill Project, have you any idea as to how much that is to cost?

A. The works, either built or building, that is the first installation was estimated, as I recall, at one hundred and sixty-one millions for an investment cost. That was not for the old City of New York alone, but that was for Greater New

York, and included arrangements for distributing water to Brooklyn and Staten Island and other points than Manhattan Island.

Q. But not designed to serve the entire population of greater New York, was it?

A. Not to supplant or displace the Croton supply, but it was intended to be available for displacing certain ground water supplies that were pumped at great expense over on Long Island, and serving as a part of the Brooklyn supply.

Q. The figure which you gave was for the cost of construction; did not include anything for capitalization or operating expenses?

A. No.

Mr. Austrian: Q. That is purely a water supply proposition?

A. Yes.

Q. How many miles does that carry the water?

A. Oh, roughly 90 miles to the city, without the distributing tunnels within the city.

Mr. Wilkerson: Q. You say you have had opportunity to study the art of water and sewage treatment, particularly in connection with certain patent suits bearing upon treatment methods. Let me direct your attention to the matter of treating a water supply. What study have you given to that?

A. You mean from the standpoint of patent litigation and the study of the art?

Q. The study of the art, yes.

A. Well, I have given a good deal of study to water supply and water purification matters, beginning in my student days at Berlin, and including quite a number of rather exhaustive tests as to different means of purifying muddy and polluted waters, and I have been connected with a good many purification projects, that is water filtration plants, from the standpoint of selecting methods and places for building purification works; also their design, supervision of construction and operation.

I have been connected with four or five different patent suits, in which the development of the art of water purification has been of importance; and I have been a witness in several of these suits; what is known as a Practical Art Expert, to testify as to the progress in water purification matters and devices through a term of years that came within the range of my personal observation and knowledge.

Q. During the last few weeks, we have had some bad

storms on Lake Michigan, as a result of which the water in our lake out there is very muddy, and health officers and doctors are telling us we ought to boil it before drinking it. According to the state of the art as it exists now, how ought that water to be treated so as to make it fit to drink?

A. To make it fit to drink, it is important to keep sewage out of that water.

Q. Well, I understand the sewage is kept out of it now. It is stirred up from the bottom.

A. With the sewage kept out of the water, still there is left, of course, the aesthetic side which is receiving more and more attention; and I presume that you have in mind the mud or silt that is stirred up by wind action from the bottom of the lake.

Q. I had in mind the statement of these doctors and health officers, who tell us we ought not to drink the water.

A. Those are not my statements; those are doctors' statements.

Q. You do not think there is any danger in drinking the water. You think they are wrong about that, if they have any such opinion as that?

A. That is a pretty broad proposition to deal with. I think if it could be shown that sewage entered the water, that is one aspect; if there is no question of sewage entering the water that gets roily a few days in the year, that is a different matter.

Q. Of course around Chicago, there is a good deal of commerce carried on; a good many ships going and coming; and naturally there is some pollution of water from that, is there not?

A. Theoretically that is so, and practically I believe to some extent that is a factor to be reckoned with.

Q. Then if that is a factor and there is enough of that so that in the course of time it does accumulate on the bottom of the lake and when there is a storm it is stirred up and makes the water unsafe, according to the state of the art as it is today ought that water to be filtered?

A. Filtered or sterilized, in the event that there is a substantial amount of sewage matter reaching the supply.

Q. How would it be sterilized, assuming it is necessary to sterilize. Let us go that far, assume it should be sterilized, what is the method of treating it according to the art as you understand it today?

A. Well, speaking generally, the art of sterilization of

water involves the application of some oxidizing chemical, either liquid chlorine, or hypochlorite of lime. There is accomplished in that way quite a material reduction in the numbers of bacteria.

There are some cases where it is difficult to apply that method with anything like the success that attends its use in general. And I believe that along the Great Lakes there is difficulty encountered of a serious practical nature in applying these sterilizing chemicals. That arises from this state of affairs: That the amount of organic matter in the water of the Great Lakes is relatively small. That means that oxydizing chemicals can be put in only in relatively small amounts. There is not any laboratory way or method by which with a sudden increase in organic matter or bacteria, such as storms might bring about, there isn't any method which reliably would show an operator how much to increase the dose of these chemicals. The result of that has been that a dilemma arises,—is the operator to put in enough of these chemicals so as to produce objectionable tastes or odors in the water as delivered to the consumers, or are the bacteria insufficiently treated with chemicals to bring about their destruction.

In a word, I mean to say that the art of sterilizing water supplies about five or six years ago met with quite a little success, quite substantial success in treating certain unfiltered waters, but in recent years, the last two or three years, it has been applied more particularly to filtered waters where the opportunity for variation in conditions of application was very small and these arrangements of work to be done are restricted to much less than they would be in the case of the waters of the Great Lakes.

Q. What about filtration as a method of handling the water supply of cities?

A. Where it is not feasible to get a water supply that is free from sewage or infectious diseases, the present state of the art of water filtration shows that very substantial improvement can be obtained as to the quality of the water initially infected and polluted; and it shows that the opportunity or likelihood of any danger coming to the users of the filtered water supply is comparatively small if the filter plant is well built, and at all times carefully operated.

Q. Have you given any consideration to the water supply and sewage problem of Cleveland, Ohio?

A. Not professionally. I have visited Cleveland and know in a general way as to the situation.

Q. What do you understand to be the method used there?

A. On the sewerage end of the proposition, I understand that some 50 per cent. of the sewage of that city still goes into the Cuyahoga River, which discharges into Lake Erie approximately at the center of the city. There is roughly 40 per cent. of the sewage that is collected in an intercepting sewer which extends for some eight or nine miles to the eastern limits of the city, and there is discharged through an outlet pipe some 2,500 or 3,000 feet off shore, in a depth of about 30 feet of water.

There is a remaining about of 10 per cent. of the sewage from the extreme western portion of the city that goes into the lake through, perhaps, one outfall sewer, possibly more than one. The water supply is obtained from the lake through an intake tunnel, the outer end of which is perhaps four miles or so off shore. The water supply has been subjected to sterilization without great success, and illustrates very clearly what I had in mind in answering one of your preceding questions. That is, in order to move to a substantial degree at all times the objectionable bacteria in the lake water, it has been found necessary by the Health Department to apply quantities of hypochlorite of lime, that resulted in quite seriously objectionable tastes and odors in the water as it reached the consumers. I believe at the present time the authorities are considering means of still further improving the conditions, in point of both sewage disposal and water supply.

Q. They will be obliged there either to filter the water, or to construct plants for the disposal of the sewage, or both, will they not?

A. They have all of those matters under advisement. I am not informed as to any official decision in the matter at the present time. They have studies under way, I believe, on both water and sewage, in point of improvement.

Q. They have no way of diluting their sewage there, except to let it go out into the lake?

A. There is no way by which they can divert it from the lake at anything within hailing distance, in point of cost.

Q. Have you studied the situation in Milwaukee?

A. I have been in Milwaukee in connection with other matters, a garbage incinerator plant, and have become familiar with some of the general features of their water supply and

sewerage problems. I am not officially or professionally informed as to their details of procedure.

Q. Have you any idea what it will cost Cleveland to take care of its sewage, according to the method which you have outlined here for Chicago, when it gets a population of 2,000,000?

A. I have not given the matter any thought.

Q. Now have you given any thought to what it will cost Milwaukee to take care of its sewage; what it would cost to take care of its sewage according to the method which you have outlined in your testimony, when Milwaukee has a population of say a million and a half?

A. No, I have not sudied that proposition.

Q. You were an expert in the Drainage Canal litigation, Missouri versus Illinois?

A. Yes.

Q. On which side of that proposition?

A. Missouri.

Q. Your own book on this subject was published in 1912?

A. Yes.

Q. You state that in connection with the preparation which you made for your testimony in this case, you have studied a number of public documents, including a report by Mr. Wisner, made in October, 1911. The report which you referred to, I will ask to have marked as an exhibit for identification, "Number 1, cross-examination of Mr. Fuller," and ask you whether that is the document to which you referred?

(The report of George M. Wisner, Chief Engineer, Sanitary District, dated October, 1911, was here marked "Number 1, Cross-Examination of Mr. Fuller.")

A. Yes.

Q. In this case of Missouri versus Illinois, on what phase of the case were you an expert?

A. In respect to the sanitary aspects, and with particular reference to the proposition of whether or not disease germs originating in the Chicago sewage might travel down the Desplaines, Illinois and Mississippi Rivers to the shores of Missouri, and particularly the intake of the St. Louis Water Works.

Q. You were on the same side of the case as Mr. Gardner S. Williams?

A. Yes.

Q. And you and he had substantially the same views on the questions that were involved?

A. Oh I would not say that. I don't remember.

Q. You both had, as nearly as you can remember now,—you were both called by the same party to the litigation, and both had the same conclusions—I will put it that way—as to the sanitary questions which were involved in the case?

A. Well, speaking for myself, I would say that my recollection is that we gave no consideration, or none of much if any consequence, to the question of nuisances in the Mississippi River, so far as Chicago sewage was related to the people living along the shores in the State of Missouri. But our viewpoint was directed in particular to the question of whether or no the Chicago sewage might not carry with it some disease germs which would reach the St. Louis intake of the public water supply, and be a material factor in explaining certain increases in typhoid fever statistics which the records of the city Health Department of St. Louis showed to have actually been experienced at that time, when I was studying the matters.

Q. Your opinion was that the discharge of the sewage down the Desplaines River and the Illinois into the Mississippi did endanger the health of the people of St. Louis in that respect?

A. That was the opinion which I held at that time, and it was predicated upon vital statistics that I believe did not hold water in point of rebuttal testimony, as to the correctness of diagnosis.

Q. That was a case where it was the statistician who was wrong, and not the sanitary expert?

A. I would not say the statistician. I believe it went back further than that. It was a question of whether or no typhoid fever, malarial typhoid fever and typhoid pneumonia all related to the same thing, and there was a difference in the classification of deaths occurring not far from the time this Drainage Canal was opened, so that the statistics did not hold water in the way in which I was led to expect they would.

Q. You have not examined the statistics on the same subject in this case, to see whether they are open to the same objection or not?

A. I have looked at them sir.

Q. Do you know, as the result of your studies of this subject in Chicago, how long after the completion of the Drainage Canal sewage continued to be discharged into Lake Michigan from Chicago?

A. Why I have stated in my direct examination what the

main facts are in point of dates as to the construction and operation of both the South Shore and North Shore interceptors, and also the date when the 12th street and 22nd street sewers were reversed in their flow. I will look them up if you like.

Q. I would like to get that date fixed, if I may, in the record, how long after this canal was opened they continued to discharge sewage into Lake Michigan. I am not speaking of the Calumet Project, but I mean the original drainage district, how long after they completed the canal did they continue to discharge sewage into Lake Michigan?

A. My knowledge of the records indicates that it was practically 1910 before the Lake Shore interceptors were completed, and that it was 1911, before the North Shore Channel was completed, to remove the sewage from a limited portion of the North Shore towns. There is still going into the lake, as I understand it, sewage from the City of Evanston.

Q. Have you any idea how much sewage was discharged into the lake, say in the year 1905?

A. No, I have not, precisely. I know the status of these diversion works, though, at that time.

Mr. Austrian: I think your question is just a little bit misleading. Of course a lot of works are not completed yet.

Mr. Wilkerson: I understand that. What I am trying to get at, as preliminary to another question which I am going to put to the witness, I understand this to be the fact, and I want to know if the witness understands this to be the fact also, that for a considerable period after the opening of the Drainage Canal, running down to 1906, anyway, there was a very considerable quantity of sewage that was discharged into the lake.

The Witness: Yes, I think there was. Just how much, I don't know.

Mr. Austrian: Let us put it around the other way: Isn't it your understanding also after the Sanitary District Channel was opened in January, 1900, a great part of the sewage that theretofore was dumped into the lake was dumped into the channel.

Mr. Wilkerson: There also continued to be a part of it discharged into the lake.

Mr. Austrian: Well, put it all in.

Mr. Wilkerson: Q. Have you any idea as to how much that amounted to in the aggregate?

A. That is the amount of sewage going into the lake?

Q. Yes, in 1905, every day, how much went into the lake?

A. I haven't a very accurate idea. I know that that was prior to the putting in service of the Lake Shore interceptor connecting with the pumping station at 39th street, for instance.

Q. Now, what do you understand to be the average, the mean outflow of water from the Chicago River into Lake Michigan? Do I make myself clear?

A. Flow of the river?

Q. Flow of the river, or to put it another way, how much on the average has to be taken out of Lake Michigan into the Chicago River to reverse the flow of the river? I am speaking about the mean now; not in times of storm, but the average?

A. I have not considered the question of the mean or average flow, but it would be very much less than the maximum of 10,000 second feet that I have been considering in its relation to the sanitary aspects of the Chicago problem.

Q. Do you understand that there is ever a time when the flow of the river is as much as 10,000 cubic feet a second?

A. Yes, I understand that that was so, and in fact that is the very essence of the design in the late eighties when the size of the canal was determined upon, but now that is not a figure of flow which would be attained every year. It is a maximum run-off, as I understand the conditions that were set forth in connection with the determination of the original size, and when that was reconsidered in point of design with the construction as actually built.

Q. Have you ever given any consideration to the determination of the number of days in the year when the flow of the river was more than 8,000 cubic feet a second?

A. No, I have not.

Q. Or when it was more than 6,000 cubic feet a second?

A. No, I have not.

Q. And do you know how small the flow becomes in times of low water?

A. Oh yes, I am aware that it would be a very small flow. I think that I have stated in my direct examination that in a rough way the flow of the Chicago River would exceed a volume of 4,000 cubic feet per second for about ten days; that is during a year of average rainfall. That is a rough, approximate figure.

Q. That is at the present time, is it?

A. Yes.

Q. About ten days in the year when it is more than 4,000 cubic feet per second is your understanding?

A. That is my understanding of it.

Q. So that with a diversion from Lake Michigan of 4,000 cubic feet per second, there would be ten days in the year when the water would flow from the river out into the lake?

A. Yes, that would be so on the premises involving rainfall alone. There would also have to be reckoned with the question of reversal of slope and the flow of river water out into the lake, due to the effect of wind action suddenly lowering the lake level, as the facts show would occur very suddenly, and to an extent at times of as much as three feet in a single hour.

Q. From which branch of the Chicago River does the most of the water come in time of storms?

A. I should say from the North Branch.

Q. What proportion of it comes from the North Branch?

A. I haven't the relative areas in mind. Do you want me to look them up?

Q. No, except in a general way; it is very much the largest part that comes through the North Branch, so that if the water of the North Branch, in whole or in part, did not go into the Chicago River in time of storm, there would not be very much water flowing through it, would there?

A. Why, any diversion of the North Branch would make an equivalent reduction in the flow of the Chicago River, as a whole.

Q. And that would be true with reference to the South Branch also?

A. Yes, whatever the facts might show.

Q. Now during the years 1904, '05 and '06, there was a very considerable amount of sewage discharged into Lake Michigan. I understand that prior to that time the cribs were moved out so that the water supply was taken from a point further out in the lake. Have you made any study of the effect of the discharge of the sewage into the lake upon the water supply of Chicago during those years?

A. Why I have considered the matter. In fact I did look into it with some care in 1906, and found that there were signs of the water being polluted on certain occasions, with an amount of pollution sufficient to cause the Health Department to advise the water users to boil the water.

Q. That was at certain cribs?

A. Probably that is so. My recollection is not clear.

Q. Do you know which cribs were the ones which were affected?

A. No, I was really under the impression that that warning from the Health Department applied to all cribs, but I may be in error. That is my recollection that it applied to all cribs.

Q. You have spoken in your testimony of the lag of the river, that is to say the time, as I understand you, when the result of opening the gates so as to let more water through would be effective at the mouth of the river. Did I understand you to say there was some difficulty in getting those gates open?

A. No, I was speaking in my direct examination of the time necessary after the gates are opened, to create a slope which would bring the water from the upper end of the canal down towards Lockport, at a rate that was intended—that is the mere opening or lowering of the Bear Trap Dam at Lockport would not necessarily effect for some hours a substantial increase in the rate of flow of water at Robey street or Western avenue.

I think that in my direct examination I was speaking of the lag solely from that angle. Of course there is also to be taken into account practically another element, and that is the lowering of the lake levels at times, due to wind action. This lowering of as much as three feet in a single hour sometimes occurs, so that the regulating works in point of fact might on many occasions through a term of years have to overcome not only the lag or time delay incident to creating the slope to pull the water from the eastern end of the canal but would also meet with complications incident to a lowering of the lake level at the same time.

Q. There would be some time elapsed between the rainfall and the time when the water would get to the river, would there not, so that if the works were opened as soon as a heavy rain commenced to fall, the effect would travel down to the mouth, by the time the water got to the river, wouldn't it?

A. There is a good deal in that thought, but it strikes me it would lead to lowering the Bear Trap Dam or the gates there whenever there is a substantial rainfall, because there is no way of telling—

Q. Why wouldn't that be practicable?

A. It would, if it would succeed, but in my opinion it would not succeed.

Q. Why wouldn't it, if whenever there was a heavy rain

it was opened so as to let a little more water through; had a man there in charge of it to close it when the water got down, why wouldn't that work all right?

A. I certainly would not want the responsibility. On paper it sounds all right, but practically I don't think it would work. I think you would have to open the gates before the rain began.

Q. Of course this back flow is a subject which has been studied a good deal by engineers, in connection with problems of various kinds, has it not?

A. Yes.

Q. Have you made any particular study of this situation for the purpose of determining just how long it takes that effect to travel up the Chicago River, or is the figure which you gave a rough estimate?

A. Well, it is not a close estimate. It is a thing that I did consider with considerable care in 1906, when I found that it was a factor that required considerable careful attention. I do not pretend to be able to state whether that lag is a 16 hour interval or 6 hour, but it is more likely to be half way between. If you are trying to get precise periods of lag, either with or without the complication of a lowering lake level due to wind action, I can't answer the question. I am giving it just approximately.

Q. The effect of that situation is this: That with 4,000 cubic feet of water going from the lake into the Chicago River, the flow of the river will be reversed as long as the amount of water in the river flowing out is less than 4,000 cubic feet per second?

A. Yes, as a general proposition that is true.

Q. If there is more water flowing into the river, and the amount that is taken from the lake is increased so as to equal or exceed that amount, the water will continue to flow away from the lake?

Mr. Adcock: I presume you are sueaking of 4,167 feet?

Mr. Wilkerson: I was speaking of any figure, for illustration; as an abstract proposition.

Q. So that water would only flow out into the lake in any event for the length of time that the amount of water flowing out of the river exceeded the amount of the diversion?

A. Yes, sir, that is obviously so.

Q. And on the basis of 4,000 cubic feet per second diversion, you think that would be about ten days in the year?

A. Well, I tried to make it plain that was an approximate statement, predicated on the rainfall aspect only.

Mr. Adcock: Are you speaking of 4,000 cubic feet or 4,167 cubic feet, when you say ten days?

Mr. Wilkerson: The ten days' statement is on the basis of the diversion of 4,167 cubic feet per second.

The witness: Yes. Let me finish my other answer there. (Previons answer read as follows: "Well, I tried to make it plain that was an approximate statement predicated on the rainfall aspect only,—")—and not taking into account the influence of wind action in suddenly lowering the lake level as much as three feet in an hour, and creating a slope lakeward in that way. I do not know what the number of days would be when a reversal into the lake might result from the lowering of lake levels by wind action.

Q. How would the total amount of sewage that was sent out into the lake as the result of that occasional change in the direction of the flow of the river compare with the amount of sewage sent into the lake where it was sent continuously from a population of 300 or 400,000 people? It would not be nearly so much would it, the total amount, of course, in a year?

A. The total amount might not be so much, but I should be inclined to think that under the influence of flood flows, it might be driven very much further away from the shore in the direction of the intake cribs, and do very much more harm to the water supply.

Q. It would be driven straight out, wouldn't it. It would not be driven to the crib at Hyde Park or the North Side. The cribs could be so located as to get them out of the zone, could they not?

A. That would depend upon the effect of wind. As I recall, the distance is not so very great from the mouth of the river, in an east and west direction, to the four mile crib and the Carter Harrison Crib.

Q. Suppose there were a diversion of 10,000 cubic feet per second, and the lake were to drop three feet, as indicated in one of your answers a few minutes ago, what would be the effect of that?

A. I have made some inquiries along that line, and it is my information that while five or six years ago, or rather in 1906, there was to be found at intervals a flow out into the lake, in recent years that has not taken place.

Q. Do you understand they are taking 10,000 cubic feet a second through the river now?

A. No, I am just using that as a basis of reasoning, in answering your question.

Q. Do you know how much they are taking now?

A. I should say roughly 7,500 cubic feet per second. I don't know exactly.

Q. How long has it been since the water flowed out into the lake, as far as you understand?

A. I have no knowledge of any flowing out into the lake since my investigations in Chicago in the Autumn of 1906.

Q. So that for the period of seven years, a diversion of 7,500 cubic feet per second appears to have been sufficient to keep the flow of the river continuously reversed?

A. So far as my knowledge goes, but I may not be fully or correctly informed.

Recess to 2:00 P. M.

After recess, 2:00 P. M.

GEORGE W. FULLER, resumed the stand and testified further as follows:

Mr. Wilkerson: Q. In the report made by yourself and Mr. Hering in 1906, estimates were given with reference to the cost of constructing sewage disposal plants for what is known in this lawsuit as the Calumet Region; and there was a comparison between the cost of constructing a sand filter plant and a contact filter plant and sprinkling filter plants; and those figures were on the basis of a population of 1,200,000 for that district, were they not?

A. Yes.

Q. And in that report there was an estimated cost of the construction of a branch of the Drainage Canal. Did you make any estimate of the cost of construction of that branch of the Drainage Canal, the Calumet Sag Channel?

A. No, I did not.

Q. The figure which you state there when you say, "The estimated cost of this proposed canal is $12,000,000," was a figure which you obtained from the engineers of the district?

A. Yes.

Q. In the figures which you gave in your testimony in this case for dealing with this Calumet region, you made an esti-

mate, I think, based upon the assumed population of the district in the year 1930, or 1920?

A. 1920, so far as treatment works are concerned and 1930 so far as intercepting sewers are concerned.

Q. What was the estimated cost of the sewers and plants for the assumed population of that district in the year which you have just mentioned? I want to get that figure in the record at this point.

A. That is sewers only, or treatment works?

Q. And treatment works, the entire plant?

A. The current estimate given in my direct examination shows $5,551,470.

Q. For which project is that?

A. That is the Calumet Project, with the intercepting sewers and pumping stations adjusted to the estimated population of 1930, and with sewage treatment works adjusted to the estimated population of 1920.

Q. And with the use of sprinkling filters?

A. Yes.

Q. How does the plant which you have suggested in your testimony in this case differ from the sprinkling filter plant which was discussed by you in your report of 1906?

A. Well, the sprinkling filters themselves would be quite generally similar. The loading, that is the sewage from a somewhat smaller population would be applied to one acre of surface. In 1913, I have estimated that the load or amount of sewage per acre would be that coming from 12,500 population. In 1906, it was a load of 15,000 people per acre. That was assumed to be the average rate. It is not the sprinkling filters themselves that account for a substantial difference between the current project and that of seven years ago. It is the appurtenances, the other works of the treatment plants that explain the differences that I described at some length in my direct examination.

Q. Yes, I read that, and there were two or three points of distinction not entirely clear to me,—probably my fault,—your figure for the use of sprinkling filters for an assumed population of 1,200,000, was $17,637,500. Now what is your assumed population in 1930?

A. 301,000.

Q. 301,000, and the sprinklers were for 1920, and what was the population in 1920?

A. 207,000.

Q. In your report for 1906, the estimated cost of construc-

tion with a sprinkling filter plant was $9,257,500, for an assumed population of 1,200,000. In your 1913 project, you have an estimated cost of five and one-half millions, which is to take care of a population of 207,000 in 1920, so far as the filters are concerned, and 301,000 in 1930, so far as the sewers are concerned, as I understand it. I want to know what there is in the 1913 project that makes the estimate so much larger per capita, so to speak, than it was in 1906?

A. I explained this at some length in my direct examination, but to recapitulate, I would state at the beginning that the current estimate is made on the basis of treating the flow of the combined sewers. In 1906, the estimate was based upon a separate system of sewers that dealt with the sanitary sewage, that is domestic wastes, and not at all with storm flows. I find that the combined system during this interval of seven years has been extended and the local authorities have not acted at all in line with the suggestion or assumption of 1906, of dealing with separate sewers.

Now, that makes a good deal of difference with regard to the size of sewers and the volume of liquid to be handled. We figured in 1906, Mr. Hering and I, that there would be a volume of sewage per capita of 150 gallons daily. Under the current estimates that figure is double that, or 300 gallons. That makes a difference in itself as regards the size of the intercepting sewers, and furthermore the current intercepting sewers now being considered, or being considered during 1913, for an estimated population of 1930, are figured upon a capacity of 900 gallons per capita; that is three times the daily dry weather flow. The reason of that is to allow the sewage to be settled and sterilized before coming to deal with the question of sterilization of storm flows.

In 1906, storm flows were not considered at all. They were assumed to go through sewers which did not receive any sanitary wastes. That is the first point.

The second point is that the pumping stations would be required, under the conditions of the 1913 estimate, to deal with much larger volumes of flow, for the reason that I have just explained. That explains the difference in point of size of the pumping stations.

The third item deals with a factor which was not considered at all in 1906, and that is aerating devices by which air would be applied to the flowing sewage, so as to prevent putrification, and to prevent bad odors arising from the vicinity of the sprinkling filters.

The next item deals with the type of settling tanks. In 1906, the estimates showed an allowance for a so-called single story septic tank; whereas the 1913 estimates deal with a two story tank of Imhoff type, with the settling compartment distinct from the sludge digestion compartment. That makes a difference of a considerable amount in the per capita cost. The sprinkling filters themselves are rated at a somewhat lower population, contributing sewage to each acre of sprinkling filters. I have just explained the difference between the loading of 15,000 people per acre and 12,500.

There is an item of sterilization taken into account in 1913, which was not considered at all in 1906. There is also taken into account differences per unit of construction work based on the experience which I obtained during the past seven years, which is considerable of a factor as I stated in my direct examination.

There is also the allowance of 25 per cent. for contingencies, engineering, administration, etc., in the 1913 estimates as compared with the allowance of 15 per cent. in 1906.

The last of these principal items is the interest during construction which I have allowed for in the current estimates, equal to the interest on the entire construction work for one-half of the period estimated by me to be required for construction. In 1906 no allowance was made at all for interest during construction.

I think the last item of difference is that of land, which was included in 1906 in the percentage addition for overhead, that is contingencies and supervision, but which in 1913 was taken separately and based on figures which were furnished me by the officers of the district, and predicated as I understand it upon a detailed examination of the facts and factors relating to land values.

Q. Not made by yourself however?

A. No, not the land values, land figures.

Q. If you had prepared figures in accordance with your project as it was in 1906, the purpose being to take care of a population as estimated in 1920, so far as the filters were concerned and 1930 so far as the sewers were concerned, what would have been the amount required for the construction of the plant, in your opinion?

A. It would have been materially less, but I don't know how much less, being a matter of estimating the significance of these factors, which I have just recited.

Q. It would have been less than five and a half million dollars in your opinion?

A. Yes.

Q. The estimate for the population of 1,200,000 in 1906, was $9,257,500, and you state there "the present population of the Calumet area of the Sanitary District being less than 200,000 would naturally require but a portion of the cost of estimated works and of their operation to be expended at the outset." If in 1906, it was intended to take care of a population of up to 1920 so far as filters were concerned and up to 1930 so far as sewers were concerned, what portion of the estimated cost of $9,257,500 would it have been necessary to expend, in your opinion?

A. It is impossible to state that accurately. Presumably the intercepting sewers, and a large portion of the pumping station structures would be built of full size, with the tanks and filters reduced on a per capita basis, and account taken of the fact that for small plants the per capita cost is liable to be materially more than for large plants. Just what the influence would be of all these factors, I cannot state offhand.

Q. Assume for the purpose of answering this question that the Sanitary District is limited to 10,000 cubic feet of water per second; that is to say that it is limited to taking from Lake Michigan the 10,000 cubic feet that may go through the main channel. What reason would there be for disposing of the sewage of the Calumet region by the dilution method instead of this other method you have outlined, unless additional water is to be put into the canal at a point further away from the lake?

A. Well, that is a question that I have not considered at great length, and would be open to the discussions and deliberations by those who managed works having a main channel and a branch channel going up into the Calumet District. The purpose of the Calumet channel primarily is to take the flow of the Calumet River to secure under the ordinary conditions its reversal, and to protect the waters of Lake Michigan from being polluted by the flow of the Calumet River.

Q. But you have suggested now for the disposal of the sewage of the Calumet region a plan by which that can be handled by an expenditure of five and a half million dollars?

A. Yes.

Q. The estimated cost of this channel was $12,000,000 in 1906. I assume that that estimated cost would be subject to increase on account of the cost of labor, the same as your

figures have been increased on account of the cost of labor; so that what I am trying to direct your attention to is the reason for the adoption of that dilution method in dealing with the Calumet region, if the district is limited in the quantity of water which it takes from Lake Michigan to that which it can handle through the main channel?

A. I have not reflected upon or considered that aspect of the case; that is I have taken into account the Calumet area as providing a certain portion of the population of the district as a whole. I have recognized clearly that the facts as I know them show that water taken through the Calumet Sag Channel would be available for diluting the sewage which would enter the Chicago River and flow down the entire length of the main channel. Those are matters of policy, matters of administration, that I have not considered at length.

Q. If the district were not permitted to take from the lake any more water than could be handled through the main channel, it would appear that there is no reason for building a channel for the purpose merely of dividing the amount of water taken from the lake, if the sewage of the Calumet region can be handled, some other way at a less expense, even from their own standopint, would there?

A. There is something to be said in support of that proposition, but in its final analysis it should take into account the benefits of reversing the flow of the Calumet River, which is a desirable thing. And I understand it also involves business considerations as to the expense of getting water to the head of the main channel. For instance, the relative cost would come up for consideration, I should say, as between the cost of the Calumet Sag Channel and enlargement, we will say, of the Chicago River. These are all matters, though, that I have not taken into account with a great deal of care, and only in a very incidental way in my deliberations on these matters.

Q. What is the outflow of the Calumet River?

A. Oh, it varies very widely.

Q. What is its maximum outflow?

A. Something in the vicinity of 15,000 second feet.

Q. How many days in the year does it get up to 15,000 second feet?

A. I do not think it would get up there every year for even a single day.

Q. How many days in the year is the maximum outflow of the Calumet River more than 10,000 second feet?

A. I do not think it reaches 10,000 second feet for any day every year.

Q. Does it reach 8,000?

A. Perhaps it does. I am not informed in detail about those figures.

Q. Isn't it a fact that there are many days on which the outflow from the Calumet River—there are many more days on which the outflow through that river exceeds 4,000 cubic feet than there are days when the outflow through the Chicago river exceeds 4,000 cubic feet per second?

A. Yes, I should think that would be so.

Q. Isn't it a fact that in order to secure with reference to the Calumet River the condition which is sought to be secured with reference to the Chicago River, namely a condition so that the river never flows into the lake, it would be necessary to divert more water through the Calumet River than through the Chicago River?

A. Yes, I think that is so.

Q. So that in order to procure a permanent condition, with the Calumet River reversed all the time and the Chicago River reversed all the time, it would be necessary to divert more than 20,000 cubic feet per second from Lake Michigan, as you understand the situation?

A. I should thing that that would be so if periods of extreme rainfall should be identical or coincident on the two water sheds. I can't say precisely whether that is the aggregate figure necessary or not, but it is in a rough way, I should think; it is not far in excess from the truth as I know it.

Q. What is the use of devising an expensive system of works for the purpose of procuring a condition which is equally as good so far as as purification of the sewage is concerned as if the Chicago River never flowed into the lake, when you have a situation whereby with any amount that has been suggested, even up to 4,000 cubic feet per second, there would be some sewage going into the lake from the Calumet River?

A. Well, the basis of that is to minimize the element of danger. The reversal of flow in the Chicago River, receiving the sewage of 2 to 3,000,000 of people, is quite a different proposition from the reversal of flow of the Calumet River, where the population is sparse and where, as I understand it, it is reasonable to assume that the population in Indiana will take care of its sewage, at least from a sanitary standpoint I have assumed that that would be the case.

Q. That is take care of it by letting it go into Lake Michigan?

A. I am not trying to solve their problems for them. I

presume the time will come when the sewage from Indiana's population will be under control, so that it will not constitute a menace to the people of the Sanitary District in Chicago, with respect to the water supply.

Q. If they do not do that, if sewage from the Indiana cities that are rapidly growing up down there goes into the lake, then it would be necessary to treat and filter the water supply of Chicago, and that without regard to the manner in which Chicago handles its own sewage, would it not, in your opinion?

A. My opinion would not justify so broad a statement, by any means. I think that the sewage entering the Calumet River from Indiana towns should be controlled by all means. The sewage of a resident of Indiana and the sewage of a resident of Illinois in the Calumet District, or the area tributary to the Calumet River should not be treated differently. The proposition from a sanitary standpoint is to take care of the sewage from the entire area. Getting to the question of whether the sewage from the Indiana towns would call for the filtration of the water supply of the entire district, that is an entirely different matter. The mouth of the Calumet River is far removed,—removed by a much greater distance from any of the Chicago intakes than is the mouth of the Chicago River.

Q. That is to say while the discharge of sewage into the lake from the Calumet and from these Indiana towns might make it necessary to filter the water from some of the intakes, it probably would not make it necessary to filter it from all of them?

A. I would not say necessary. It would make it—

Q. Advisable?

A. Much more desirable; and in the event that the sewage would not be kept out of the Lake Michigan waters in the vicinity of the intake.

Q. Just as if some sewage for a few days in the year would flow from the Chicago River into the lake, it might be necessary to filter the water from some of the intakes, but not from others that were far away from it?

A. That might be so. It would call for a much closer analysis than I can give offhand of the proposition as you state it.

Q. Have you, in your study of this subject, given any consideration to the proposition that it is only a matter of a few decades when it will be not only advisable, but perhaps neces-

sary for Chicago to filter or otherwise treat its water supply from Lake Michigan?

A. No, I have not so considered it because I believe if the sewage is kept out of Lake Michigan, the hygenic aspects will then be taken care of satisfactorily. There is still left, of course, the matter of the aesthetic side, the occasional turbid water that comes following heavy storms.

Q. Is that purely aesthetic, or is there an element of health that comes from this mud or whatever it is that is stirred up from the bottom of the lake?

A. That would not be so at all, in the event sewage is all diverted from the waters of Lake Michigan, and the influence of shipping with reference to pollution is kept under control, which I understand has been considered very carefully by the authorities at Chicago.

Q. What authorities do you mean?

A. I understand it has been considered both by the health authorities of the city and by the district. Personally I have not made a special study of that fact. I mentioned it to emphasize this proposition that the hygienic needs of filtration do not stand in my mind if all effects of pollution of the lake waters by sewage are cut out, are eliminated.

Q. I think you said you had read the report of Mr. Wisner. I just call your attention to one statement, the statement of a general proposition. He says: "Today standards of sanitary science are much higher, and in consequence the demand is rising for the filtration of all surface supplies. It is thought that in the future filtration of the water supply of Chicago will be urged. Should untreated, or even treated sewage be discharged into the lake in the vicinity of the intakes, the water should be sterilized and finally filtered. Such discharge of sewage is not contemplated in the plan of the Sanitary District." So far as the filtration of the water supply is concerned, where treated sewage is discharged into a lake, do you understand that is the view which is generally taken by sanitary engineers today?

A. Generally speaking I think that is the viewpoint, if it is not readily feasible to keep the sewage out of a water supply.

Q. Now let us look forward, not to 1920 or 1930, but let us look 40 years ahead or 50 years ahead in Chicago, and let us assume we are dealing with a population of 6,000,000 people there. It would be necessary, according to the standard of dilution which you have indicated in this case, with a popula-

tion of 6,000,000 in Chicago, either to take from Lake Michigan 20,000 cubic feet of water per second, or to filter the water supply, wouldn't it?

A. No, I don't think so. There might be the purification of the sewage and the sterilization of the sewage with somewhat less than the volume of water diverted that you speak of, so that the filtration of water is not absolutely a criterion of what the future will bring to that community.

Q. How much less than 20,000 cubic feet of water per second do you think would take care of the sewage of a population of 6,000,000 people, by treating the sewage before it was discharged into the canal?

A. That would depend upon the amount of treatment given to the sewage, of course. The figure which I considered in this case has dealt, so far as the Chicago River is concerned, with an amount to ensure the reversal of flow at all times down the channel, and to prevent the sewage going out into the lake and contaminating the water at the intake cribs.

I have not given any consideration to the proposition of taking more than the 10,000 second feet through the Chicago River, plus 4,000 second feet flow through the Calumet Sag Channel, because those are the figures which I find in my consideration of the project put before me, all of the projects put before me.

Q. It is perfectly obvious, even with a diversion of 14,000 cubic feet per second, after the population of Chicago and vicinity, which is served by this system, increases to more than 4,200,000, one of two things will have to be done, either there will have to be more water taken out of the lake, or there will have to be some system devised of treating the sewage?

A. Yes, that is a fair general proposition.

Q. It is only a matter of a few decades until the same question will be up again in that form?

A. I could see how that might arise.

Q. And the only solution is more water, or some other method of dealing with the sewage?

A. Yes, I think that is true as a general statement. I was commenting, in my early answers, on a proposition dealing with a quantity named by you, that is 20,000 second feet diversion; that is the sewage should be diverted from the lake in order to protect the lake waters. That is the first proposition that my mind insists upon, hygienically, and if there should be diverted in excess of that water which would be available for

dilution of sewage, that takes care of sewage disposal matters. If water is not available in excess of preventing the reversal of flow, and a population springs up so that treatment works are required, why that is a matter which I have not considered at all, the relative aspects of added quantities of water for sewage dilution as against sewage treatment works. I have dealt specifically here with quantities as I find them, and particularly with reference to 4,167 second feet.

Q. Assuming for the purpose of answering this question that a diversion of 4,167 cubic feet per second properly utilized by the Sanitary District will ensure a reversal of the flow of the Chicago River at all times, have you given any consideration to the cost of disposing of the sewage of the city, on the assumption that there would be 4,167 cubic feet of water per second on the average going down the Chicago River with the flow reversed? Have you given any thought to the methods by which the sewage could be partially purified so as to dispose of the sewage through the canal with the 4,167 cubic feet per second?

A. I have studied sewage disposal projects dealing with the assumption that 4,167 second feet were to be the flow which would be diverted down the canal, but I have not considered it on the assumption that that would secure a reversal of flow at all times, and thus protect the water supply at Chicago at the present intakes.

Q. Just what use is made of this 4,167 cubic feet of water per second, which is taken from Lake Michigan, in the projects that you have suggested here?

A. It has been used to oxidize the settled sewage coming from the Loop District and the West Side District and thus save the expense of subjecting that settled sewage to treatment on sprinkling filters.

Q. What becomes of that according to your project when the flow is reversed, where does the sewage go? I want to get in mind the ultimate disposition of the sewage from the different parts of the city according to your project?

A. All treated sewage and all storm water, with a flow of 4,167 second feet would go down the main channel to the lower end of the main channel at Lockport, so long as the storm flow would not bring about a reversal. When the flow of the Chicago River and its tributaries would exceed 4,167 feet, then under the projects which I have described or estimated upon, this treated sewage, filtered sewage, settled sewage, also sterilized sewage would go on out into the lake.

Q. I want to be sure that I understand that. In your project, the sewage from the Loop District and the West Side is discharged into the Chicago River. You have before you now the map which was identified in connection with your direct examination?

A. Yes.

Q. What I am trying to get into my mind is this: According to your projects, what is done in the first instance with the sewage from the Loop District and the West Side, where does it go?

A. That is taken out to settling basins in the vicinity of Kedzie avenue, and if there is available 4,167 second feet of lake water for dilution, then that settled sewage from the West Side District and the Loop District would be sent into the canal, and its oxidation would be taken care of by this diluting lake water and sprinkling filters which are shown on this map; in laying out projects of various natures, the site for sprinkling filters shown here between Harlem avenue and South 64th avenue would not be required.

Q. That is to say there is sewage which is put into the Chicago River from the West Side and the Loop District which in times of storm, when the flow is more than 4,167 cubic feet per second, goes out into the lake before it has been filtered, or after being filtered?

A. It would not be filtered at any time, if that volume of lake water is available for dilution, but that sewage after sedimentation would be sterilized according to the projects which I have described in my direct examination. That sterilization applies to the flow of all districts.

Q. Is it sterilized in big storms?

A. All storm overflows would be sterilized when they exceeded three times the dry weather flow, and there would go through the settling basins the storm flows up to three times the dry weather flow; so that everything would be sterilized, dry weather flow, storm flows, everything would be sterilized coming from the existing sewers by the projects which I have described.

Q. By three times the dry weather flow, do you mean that that is the maximum flow?

A. That is the maximum flow which would go through these settling basins of the two story Imhoff type, and which would go through intercepting sewers leading to sprinkling filters in the instance of those areas where the sewage after sedimentation is subjected to filtration.

Where the sewage flow at times of storm should happen to exceed 900 gallons per capita, or three times the dry weather flow, then there would be applied sterilization processes for that excess flow; what I have spoken of in my direct examination as storm overflows, so that sterilization would be applied to all of the discharge from all of these sewers at all times; either the treated or settled sewage, treated sewage or the excess which I call storm overflow.

Q. Now let us see: Unless this sewage is settled, it cannot be sterilized, can it? I am speaking now about the disposition of this sewage in times of storm. What I am trying to find out is whether according to this project here there will be any time when there will be sewage go out into the lake without being sterilized, settled and sterilized?

A. Well, these storm overflows are what I think you have in mind, and I would say in that regard when the storm flow exceeded three times the dry weather flow, then these excess flows, storm overflows would not go through the regular settling tanks but would go through what I have called contact tanks. That is there would be a detention period of, I think it is ten minutes under the extreme maximum conditions of rainfall, that is 60 cubic feet per second per square mile. And there would be at all times some sedimentation in these contact tanks where the sterilizing agent would be applied; with rainfalls any less than the extreme maximum to give a runoff of 60 cubic feet per second, this ten minute period of detention in the contact tank would of course be correspondingly increased.

Q. But there are times when the sewage would find its way into the lake without having been filtered?

A. Without having been filtered, on the assumption that filters were not necessary for this West Side and Loop District because that settled sewage could be oxidized by this volume of lake water.

Q. When the river flow was reversed?

A. No, at all times, that is the sprinkling filters have for their purpose essentially the oxidation of organic matter to prevent putrifaction. They are not considered by me in these projects as devices for removing the disease germs and making the effluent safe for drinking water. They will remove, perhaps, 80 or 90 per cent. of the bacteria in the liquid applied to them. But to protect the water supply of Chicago at the respective intakes against disease germs coming from the Chicago sewers at times of heavy storms when there would

be no reversal, with an allowed flow down the canal of only 4,167 feet to prevent that pollution of the water supply, I have provided for the sterilization of all liquid which would come from the sewers, whether it is settled or whether it is filtered or whether it is a storm flow that goes into a simple contact tank in order to deposit the coarser solids and give opportunity for the flow of the sewers to come in contact with the sterilizing liquids.

Q. What approximately is the population of that portion of the district as to which the 4,167 cubic feet would be utilized, as you have indicated?

A. That flow of 4,167 second feet of lake water down the canal would be utilized in oxidizing the sewage after sedimentation from the West Side and Loop districts, which would have a resident population in 1920 estimated roughly at 970,000, plus a floating population estimated at 300,000.

Q. About 1,200,000 in all?

A. 1,270,000 in all.

Q. Now the result of this method of handling sewage would be that in times when the flow of the Chicago River was not reversed, the sewage from that population would find its way into Lake Michigan, with no other treatment than the sterilization which you have described. Is that right?

A. That is true, if you consider the sewage as having been subjected to sedimentation as well as sterilization.

Q. What good does the sedimentation do during a storm?

A. It keeps the accumulation of solid fecal matters from building up on the water courses, stream beds, and it also aids in bringing about effective sterilization.

Q. The most difficult conditions under which to sterilize the sewage are the storm conditions, are they not?

A. Yes, that is so with respect to adjusting the amount of sterilizing agents to a fluctuating volume of liquid, and during the first flushings, so called of sewers when heavy rains begin, there are solid matters washed from the walls of a sewer. It is feasible to sterilize the liquid portion of sewage and the exterior surface of particles in suspension. It is not feasible to kill disease germs that are situated, for instance, in the interior of a solid particle of fecal matter. The sedimentation has been considered as a part of this project, in order to deposit solid fecal matters so far as practicable rather than to allow them to get out into the stream bed of the Chicago River and its tributaries.

Q. Well now if it is all right to have that sewage find its

way into the lake with no other treatment than this sterilization under these storm conditions, why the necessity of these sprinkling filter plants; why not sterilize the sewage before it goes into the lake, the other sewage, in the same way?

A. The flow from all these other plants would be sterilized. I have endeavored to make it plain that sprinkling filters for this West Side and Loop District are omitted from my projects solely by virtue of the fact that the oxidation of the organic matter coming from this tributary population could be secured by the flow of the 4,167 second feet. If there should be sufficient flow of lake water, there could be omitted the sprinkling filters from this so-called Lawrence avenue project; but there is not enough lake water under the assumption of 4,167 second feet to prevent putrifaction of settled sewage coming from this northern area; and hence to secure a stable, non-putrifying liquid, sprinkling filters would have to be used at all other locations than this one that I have spoken of, namely the West Side and Loop District.

Q. I still don't understand why if in times of storm it is proper to send that sewage out into the lake, with no other treatment than this sterilization, it is not proper at other times to send the other sewage out into the lake with no other treatment than the sterilization, without filtering it, without the sprinkling filters?

A. The sprinkling filters are figured on to prevent putrifaction of these waters and foul stinks arising to produce nuisances. There is not enough water with 4,167 second feet available for dilution to prevent putrifaction, except for this area that I have just spoken about, shown here as the West Side project.

Q. I think it is Mr. Wisner who in his report speaks of the aeration of sewage for the purpose of preventing stench and other offensive features. Why couldn't you do that, instead of having sprinkling filters?

A. I think you might, but I think it would be too expensive. I think sprinkling filters are a cheaper means of oxidation.

Q. Than the aeration?

A. Than the aeration, to the point of getting a non-putrescible effluent.

Q. You have been utilizing this 4,167 cubic feet per second, used that for the purpose of oxidizing, you say, for a permanent population in 1920 of 970,000 and a floating population of 300,000, making a total of 1,270,000. Now isn't it a fact

that that quantity of water can be made more efficient by some treatment of the sewage, or haven't you treated the sewage in such a way that the 4,167 cubic feet per second can be utilized in handling the sewage of more than that number of people?

A. I should be disposed to say that it might be used to handle the sewage from a somewhat larger population, but whatever that increase might be in excess of the 1,270,000, I have assumed in these estimates as a factor of safety. I have realized that the division of the future population of Chicago into different sewerage districts must of necessity be somewhat arbitrary, and for that reason I have taken this largest district as the one from which to omit sprinkling filters. Theoretically, the point which you mentioned has some measure of support, but I have used it as a factor of safety which a few years would eliminate.

Q. If by settling and sterilization you could add, adopting Mr. Hering's figure, which I think is 33 1/3 per cent. to the efficiency of the water, that would mean this 4,167 cubic feet in the way in which you have utilized it could take care of a population between 1,600,000 and 1,700,000 people, so your factor of safety there adds considerable to the expense of this project, doesn't it?

A. It does, looking at it in that light. And it does in a practical way where a factor of safety must be provided.

Q. As a matter of fact, dealing with factors of safety and things of that kind, it is only a matter of a little time until the 10,000 cubic feet, so far as this dilution method is concerned, would be wholly inadequate, so with a diversion of 10,000 cubic feet from Lake Michigan, there is nothing permanent in that way of handling the sewage?

A. Well, I can see how that might be reasoned out, but on the other hand in the heart of a large busy metropolis, for many hours of the day a factor of safety in point of dilution would have to be dealt with that would not apply to the city as a whole. There is some margin there, I will say that, as I have already explained, but I do not think it is an unreasonable one at all, in view of all the facts and conditions.

Q. And it is also true that there is another factor of safety in the fact that the sewage of a floating population can be taken care of with a smaller quantity of water than the sewage of regular residents?

A. Not if the floating population are resident within this area 24 hours per day, it certainly is not so. If they are resi-

dent there only eight or ten hours, I can see how that would be a factor.

Q. By floating population, you mean those who come into the city and stop at a hotel for a little while and go out?

A. Yes, temporary residents rather than continuous residents of the community. Of course there is also from this district some trade wastes to be dealt with that are not peculiarly or characteristically Chicago trade wastes. By that I mean not the wastes of the stock yards district or packing houses, tanneries on the north branch, and the like. In all business districts there are wastes other than heavy trade wastes.

Q. Let me direct your attention to a matter about which I have asked you one or two questions already, but I want to put it in a little different form so as to make sure that I have your full explanation: In your direct examination you state that with a diversion restricted to 4,167 cubic feet per second, it would be necessary to settle all the sewage as well as to provide sterilization for all the sewage; and also sprinkling filters to render stable and non-putrefactive the flow in excess of that which could be diluted with the 4,167 cubic feet per second. Why, having settled and sterilized all of the sewage from the entire district is it necessary to still further treat it by sprinkling filters? Have you anything to say as to that, in addition to what you have stated already?

A. I have endeavored to make it as plain as I could that if you did not have sprinkling filters for the Lawrence avenue, North Shore, 39th street district, for instance, you would get a putrefaction of the flowing liquid down the canal. It would be a black bubbling stinking nuisance, and it is necessary to keep that on a stable, non-putrifying basis, in order to be able to send that down the valley, send that liquid down the valley of the Des Plaines and Illinois Rivers, and keep a condition in point of nuisance as good, or keep the conditions as free of nuisance as would be the result with this dilution of 3 1/3 cubic feet per second per thousand population.

Q. In these districts outside of the Loop District and the West Side District which we have been considering, what is the course the sewage takes? Let us take the district on the South Side, that sewage goes into the sewers, and where—

A. Take the South Side for instance, the sewage would flow through the existing sewers into the present Lake Shore interceptor, from 87th street we will say to 35th. That portion of the South Side would have its sewage then going

through intercepting sewers to 39th street pumping station. It would be subjected then to sedimentation in settling tanks built at the Lake Shore and adjoining the 39th street pumping station. That settled sewage then would be pumped through conduits on west to this area south of the main channel between Ridgeland and Harlem avenues, and there would be added to this flow in the delivery mains the settled sewage lifted by other pumping stations along the route. All of the sewage then after having been settled is put on to sprinkling filters in the vicinity of Summit, and after having gone through the sprinkling filters, and little small settling tanks following the sprinkling filters, it would flow after sterilization into the main channel.

Q. All of the sewage according to your plan then finds its way ultimately into the canal. None of it goes into the lake?

A. None of it would go into the lake except under conditions where the rainfall produced a flow in excess of the 4,167 second feet. When the flow was less than 4,167 second feet, then the flow would all go down the main channel as at present.

Q. And that is true as to both projects A and B?

A. That is true as to both projects.

Q. In your consideration, Mr. Fuller, of the purifying effect of the 4,167 cubic feet per second of lake water, are you considering as a major factor the oxygen content of that diluting water?

A. Yes, I should say I am, in the sense that that water is used to prevent putrefaction, and therefore serving as a substitute for sprinkling filters which are used under conditions where the dilution method is not available.

Q. In what other way than oxidation would you prevent putrefaction by that water?

A. I don't know of any other way than by oxidation or by keeping sewage matters diluted in a sufficient volume of water, so that if there is no direct oxidation there is the prevention of the negative, that is prevention of putrefaction.

Q. What do you assume the oxygen content of the lake water to be when it enters the canal?

A. Whatever the facts show.

Q. If you don't know what the oxygen content of the water is, how are you able to tell what its effect would be in purifying the sewage?

A. By satisfying myself that 3.33 cubic feet per second per

thousand population is as small a dilution as the oxygen content or any other factors taken with it justify, in point of dilution. I am talking, not only of oxidation with the oxygen content, but everything that goes with it as a mass.

Q. That was for crude or raw sewage was it not?

A. Yes.

Q. And not sewage that had been subjected to treatment. Do you know what the average oxygen content of the water is as it enters the canal?

A. Not from memory. I can easily look it up.

Q. What portion of the oxygen content of the 4,167 cubic feet per second do you assume as available for the purification of organic matter?

A. Theoretically it is all available, with the proviso that there ought not to be allowed to occur an exhaustion of oxygen at any point at any time. There is some difference between theory and practice. So long as you have a plus oxygen content at all times and all places you will not get into trouble with putrefaction from the theoretical standpoint. Practically I believe you should have some margin of safety, and I have considered that with much care. The different factors have to be considered somewhat differently in different places. I believe at the foot of the canal, for instance, at the foot of the Chicago Drainage Canal at Lockport it would be very highly desirable to have an oxygen content, say, of about 1½ parts per million. That is more than is secured for the summer months under the present conditions, and as I stated on my direct examination, I believe this legal minimum ratio of dilution, if it were to be changed at all, should be increased.

Q. What would that represent in per cent. of saturation at ordinary temperatures?

A. It would range from 20 to 30 per cent. during the warmer half of the year, depending on the temperature of the water.

Q. If the water enters with 90 per cent. and leaves with 25 per cent., then you have 65 per cent. available, is that right?

A. That is a correct calculation.

Q. You are familiar with the statement of Mr. Hering in his report of October 15, 1907, page 6, to the Honorable Robert R. McCormick, president of the Sanitary District of Chicago, to the effect that: "As the population sewering into the canal is now estimated at 1,887,472, the ratio is 2.75 cubic feet per second for 1,000 persons, and the results with this ratio are satisfactory, but closely approach the limit."

A. I have noted it, yes.

Q. And have had it in mind in your testimony about this ratio of dilution?

A. Yes, I have considered that.

Q. It is a statement that is entitled to some weight, is it not, in view of the standing of the man who makes it?

A. Yes, it is, but to take it very literally it ought to carry with it a statement of the season of the year.

Q. It is October, 1907?

A. Yes.

Q. When the report was dated. I do not know when the study was made.

A. October is a month in which you do not get the complications you do in winter, where you have ice preventing the oxygen of the atmosphere reaching the sewage as it flows down the canal and rivers below, and you have more oxygen in the water of Lake Michigan than you have during the heated period in summer. I do not find any fault with that statement, and I will take that into account in making the statement which I make in respect to the legal minimum ratio of dilution.

Q. But there is no allowance there made for a floating population apparently, is there?

A. Not that I have noted.

Q. In what fundamental respects do your projects A and B differ from each other?

A. In the first place, Project A takes the flow of sewage from the present sewers, whereas in Project B, an entirely separate system of sewers would be built in which to get the household waste at their point of origin and deliver them to the pumping stations and treatment works.

In the Project A, the storm water, that is the rain water falling upon the streets, roofs, parks and vacant lands would reach the water courses through the existing sewers together with the household wastes.

In Project B, storm water would flow through the existing sewers used exclusively for storm water, and with the household wastes in an entirely new system. The treatment works would be substantially along the same lines in the two projects, the intercepting sewers, pumping stations would be somewhat smaller with Project B because they would not deal with a portion of the storm water.

Q. So far as any of the sewage finding its way ultimately into Lake Michigan is concerned, there would be the same

situation when the flow of the Chicago River was such as to cause the water to flow out into the lake, would there?

A. I should have said in answering your preceding question that in Project A the storm flows would be subject to sterilization, whereas in Project B, keeping the storm water by itself, it would not be subject to sterilization.

Q. How would it be treated before it found its way into the lake, in times of storm and flood?

A. In Project B, there would be no treatment at all of street wash, horse manure and things of that kind.

Q. That would go into the lake after—

A. That would go into the Chicago River and water courses and if the flow of the river should bring about a reversal, then it would go to the lake.

Q. How would the domestic sewage be treated in Project B?

A. That would be subjected to sedimentation and sterilization with sprinkling filters used for areas other than the West Side and Loop districts.

Q. But take the West Side and Loop districts, how would that be treated in times of storm or flood, would that find its way into the lake in Project B?

A. Yes, in Project B if the sterilized and either settled or filtered sewage reaching the canal and mingling with the other waters if the flow of the Chicago River should be outward to the lake, then the treated sewage by Project B also would reach the lake.

Q. Would be treated in the same way in Project B as Project A?

A. Yes, that would be true with the exception I have just spoken of, that the storm flows in Project A would be sterilized. In Project B, they would go through the existing sewers without household wastes, and receive no treatment at all.

Q. In view of the fact that in Project B there would be some water which would find its way into the lake without any treatment, which would be treated in Project A, in view of the fact Project B is the more expensive, what was the purpose of suggesting Project B?

A. The purpose of suggesting Project B was to keep the sewage removed from a really bothersome proposition, and that is dealing with storm overflows. They have been assumed to be sterilized, but I do not believe that in the state of the art of sewage treatment today, a project related to a

water supply would be considered as perfect, or would approach as near perfection, where storm flows enter into the reckoning, as would be the case if separate sewers were to be built and the flow of the household wastes alone were subjected to treatment.

Q. In your Project A, what per cent. in your opinion of the total organic matter would be removed in the primary settling tanks?

A. By Project A?

Q. Yes?

A. I should say that it would be roughly 25 per cent.; that is of the putrescible organic matter.

Q. And what per cent. in the supplementary tanks which follow the sprinkling filters?

A. Well, taking the sprinkling filters and the supplementary tanks, it will bring the total percentage of removal to something like 70 per cent. with the residual so stable that with the oxygen content, coming from the aeration at the sprinkling nozzles, it would be a stable effluent under all ordinary conditions. That is to say it would not putrify upon standing.

Q. Can you divide the percentage which would be removed in the sprinkling filters and the percentage which would be removed in the supplementary tanks?

A. No, I cannot readily. It would vary tremendously. During the spring months, there is a good deal of accumulated material from these sprinkling filters that seem to unload. The stored organic matter for weeks at a time has to be dealt with in figuring upon what the percentage of removal would be by final tanks. I never have attempted to get an average figure in mind, as between the sprinkling filter removal of organic matter and that of the supplementary tanks.

Q. Have you given any consideration to the methods used in Milwaukee for disposing of their sewage?

A. You mean the methods now in vogue there?

Q. Yes?

A. Practically none at all. I know they are not satisfactory.

Q. And the projected methods?

A. No, I have never seen the final report, except as summarized briefly in the technical press.

Q. Assume a diversion of 10,000 cubic feet per second from the lake, which on your statement of the ratio of dilution re-

quired would take care of a population of 3,000,000 people. Now assume that the amount which may be taken from the lake is limited to 10,000 cubic feet per second, and it becomes necessary to provide for the sewage of a larger population than the 3,000,000, would the projects available for taking care of that sewage, after you have utilized to the full extent the water for the purposes of dilution, be the same as the ones which you have indicated here as Project A and B, with the exception of the provision which you have made for sterilizing the water when the river with the smaller amount of diversion from the lake in times of storm flows towards the lake?

A. Well, the project would involve no sterilization, as you say in your question.

Q. Yes?

A. Because then the protection of the Chicago water supply would not be a point at issue.

Q. Aside from that would it be the same substantially?

A. It would involve the consideration whether the best investment would come from settling the sewage from a portion or all of the population, and letting that settled sewage go down the channel, or whether from a certain smaller portion of the district the sewage would be subjected, both to sedimentation and the sprinklers. That is a question I can't answer offhand because it takes into account other factors of course, such as getting the settled sewage to suitable sites for sprinkling filters. The sprinkling filters on the basis of per capita cost will probably cut down the required dilution per capita more than will settling tanks. That is one end of the string, and the other is that settling tanks would be applied at the outlet of existing sewers, and not require pumping stations and long delivery conduits to reach suitable and isolated areas such as are necessary for sprinkling filters, so that I cannot state offhand how those factors would balance and indicate ultimate economy. Which ever was cheapest would be the best, where it is simply a matter of preventing sewage nuisances in the Chicago River and various water courses associated with populations in excess of 3,000,000 people, and with the protection of the Chicago Water Supply out of reckoning because of the reversal at all times of the Chicago River.

Q. After the city has outgrown the dilution system with a diversion of 10,000 cubic feet per second, and it becomes necessary, assuming that the district is not allowed to take

any more water out of the lake, to resort to other methods, other conditions remaining the same, would it cost about as much to provide for the disposition of the sewage of an additional 3,000,000 people at that time as it would now to provide for the sewage of the first 3,000,000, with the exception of this sterilization of the sewage which may find its way into Lake Michigan because of the insufficient diversion of water from the lake to reverse the flow at all times?

A. Well, assuming the unit prices of labor and materials the same?

Q. Yes?

A. I think it would be true as regards settling tanks and sprinkling filters. The question of intercepting sewers is a very complicated one. It depends upon the density of population and the manner in which sewage might be assembled at suitable sites. That I really don't know how it would be. The pumping question would similarly be a thing that I can't forecast upon.

Q. They would be figures which might be said to fall in the same general range?

A. Cutting out sterilization and interceptors and pumping station, I should say that would be generally true; that is, it does apply, labor and materials being the same, to the settling tanks and to the sprinkling filters. I ought to say that with the sterilization eliminated, I think that the intercepting sewers could be somewhat smaller than with project A, but not smaller than project B.

Q. So that if the district is permitted to utilize this 4,167 cubic feet per second, and if at no time it were to be permitted to take more than 10,000 cubic feet per second, if that were a fixed fact, it never could take more than 10,000 cubic feet per second, then what we are dealing with here is the disposition of sewage, which by the dilution method would be taken care of by a diversion of 5,833 cubic feet per second, and that is as I understand the comparison figures which you put into this record.

Mr. Austrian. In other words, he took the 4,000 from the 10,000 and got the figure which you mentioned, is that right?

A. These projects which I have described will dispose of the sewage without nuisance for a population equal to that which would be taken care of by the 5,833 cubic feet per second, and also provide the best method other than by dilution

with a diversion of all sewage down the channel, for the protection of the Chicago water supply.

Adjourned to Friday, November 28, ten o'clock A. M.

Friday, November 28, 10 A. M.

Parties met pursuant to adjournment.

GEORGE W. FULLER, resumed the stand for further cross-examination by Mr. Wilkerson, and testified as follows:

Q. In these projects which you have outlined in your testimony, Mr. Fuller, you have referred to the secondary sedimentation or to the sedimentation after the filters, I think?

A. Yes.

Q. Just what do I understand you have in mind as to the purpose of that particular part of the operation; what value do you attribute to that?

A. The sprinkling filters retain a good deal of the very finely divided particles that are suspended in the sewage, and which pass through the primary sedimentation tanks. They seem to adhere to the stones comprising the bed of the sprinkling filter. At intervals they are released and the effluent coming from the sprinkling filters at times will contain these little detached filaments from the surface of the stone, and some of them will be perhaps as large as the end of your little finger. They vary in size, and at certain seasons of the year, particularly at the end of the winter, when warm weather comes in the spring, there will be a relatively large amount of these particles detached. The purpose of these secondary settling tanks is to remove from the sprinkling filter effluent the suspended matter which comes from the sprinkling filters. These secondary settling tanks would also serve another purpose, in that they would be of aid in allowing sterilization to be made of the sprinkling filter effluent. It is the settling of solid matters, however, which is the main purpose of calling for the secondary settling tanks.

Q. Isn't it your opinion that the particular thing could be accomplished in a less expensive way than in the way you have outlined?

A. No, I think not. It is my regular practice to provide secondary settling tanks for sprinkling filter effluents, and that has been done in every project with which I or my

office has been connected, with possibly one exception, where Mr. Hering, I believe, under unusual conditions at Atlanta in point of a turbid water in the stream where the effluent was discharged, he omitted them, but other than at Atlanta, Ga., I know of no sprinkling filter project in which secondary tanks have not been a part of the design, and actual construction of works has followed.

Q. How about the plant at Batavia, N. Y., are you familiar with that?

A. I do not recall it at the moment. My impression is that they have secondary settling tanks.

Q. You are not sure about that?

A. I would not state positively. I was not personally connected with that plant, although it was designed by Hering & Fuller, but Mr. Hering was the one having immediate oversight of the work.

Q. If Mr. Landreth says as a matter of fact they do not, you would not be surprised if that were true?

A. If that is the fact, I would not be surprised. I do not remember specifically what the facts are.

Q. What I mean is it might be true?

A. It might be.

Q. Now, part of your method of treating this is by aeration of the sewage. I want to ask you a little more about that. What is the purpose of that?

A. The aeration feature of these projects which I have described is embodied in the intercepting portion of the works. The purpose of aeration is to prevent the sewage becoming septicised, so to speak, or becoming decomposed to a point of producing very foul odors. It is found that in a number of places where sewage has reached an advanced stage of decomposition and is applied to sprinkling filters from a series of nozzles a good deal like lawn sprinklers, that very offensive odors are transmitted a considerable distance away from the plant itself. The purpose of aeration in these projects which I have described is to prevent the sewage becoming black and foul, decomposed, or what is technically an anaerobic condition, that is, decomposition in the absence of atmospheric oxygen.

Q. You have discussed in your book, I think, this matter of aeration, to some extent, have you not?

A. I think I have spoken of it some, yes, from several different angles.

Q. Have you made any study of the subject since your book was published?

A. Yes, I have.

Q. What study have you made? What has been the result of your study since the publication of your book on the subject of aeration of the sewage?

A. The result has been such as to cause me to consider it to be highly desirable, and in fact necessary, where sewage has to be transmitted for long distances, and to prevent this offensive decomposition about which we know more to-day than we did at the time my book was written.

Q. That is, to put it not in technical language, the effect of it is by getting the air in the water, you increase the efficiency of the water in handling the sewage, is that it?

A. There is something in that viewpoint which you speak of, but I think it is hardly a commercial proposition to use atmospheric oxygen for the purification of sewage. I consider aeration applied to the flowing sewage in interceptors more in the nature of what might be called a preservative; that is its purpose is to prevent putrefaction with its attending bad odors. I am not setting forth aeration as a part of the purification project in these various schemes described for the Chicago Sanitary District.

Q. That is one branch of your art in which studies are being made all the time, in which there has been some development in recent years, has there not?

A. It has been studied a good deal, yes, but the practical advance in the art is confined to just these lines I have spoken of, in connection with the Chicago project.

Q. This matter, this whole question of the disposal of sewage is one as to which the art has been undergoing somewhat rapid change?

A. I think that is true so far as the detail is concerned. It is not so true by any means with respect to what might be called the basic principles involved.

Q. It is now in process of development, in the way in which you have spoken?

A. To some extent, I think that is so, as regards details for utilizing the principles, which have been known for some time.

Q. And in this question of taking care of water supply and handling sewage, as our large cities grow, there are two things for which the dilution method is used to be accomplished, are there not: The first is saving the water, that is to say preventing the waste of the water, and the next is to increase the efficiency of the water which is used for the purpose of diluting and taking care of the increased quantity of sewage.

What I mean is it is found that those are the two things that you have to try to accomplish, is it not, in a great many cases?

A. There are cases where it is quite important to make the diluting water go as far as practicable, and if I understand you rightly the amount—do I understand that the amount of sewage is one of the features which you raise?

Q. Preventing the water from being used in an extravagant and wasteful way?

A. It is desirable to keep the volume of water supply per capita on as economical basis as practicable. In this country the use of water is much more lavish, of course, than it is in European cities.

Q. Yes, I had in mind the statement in the report of Mr. Wisner as follows: "The use of water in Chicago to-day, as stated by the Department of Public Works, is extravagant and wasteful. A large volume of water makes the question of sewage disposal more expensive by increasing the size of settling tanks and sewers and pumping works. It is believed if the dry weather flow were lowered, the economical point to intercept would also be lowered. The annual cost of pumping sewage will also be reduced. Metering the water service throughout the city is the only remedy to prevent waste." In your project you have assumed a per capita consumption of 230 gallons, have you?

A. I took a dry weather flow—

Q. Or 300 gallons?

A. I took the dry weather flow of sewage as 300 gallons per capita on an average, and based on actual measurements at Chicago.

Q. That is to say, based on the figures which were given to you by the Sanitary District?

A. Yes, by the official records of the district. That takes in not only the water supply, but also some ground water leakage into the sewers.

Q. And you prepared no estimates based upon an assumption that this wasteful and extravagant use of the water would cease, and the consumption per capita would be brought down to a reasonable basis, did you? You simply took it as the figures were given to you, as you found it in the present wasteful and extravagant way in which the water is used?

A. I took things as I found them, but I also have been informed that there has been within the last few years quite a reduction in the amount of water used per capita, and compared with what was the volume used per capita in earlier

years. The reduction in the volume of water supply is a good deal easier thing to talk about on paper than it is to accomplish in actual practice.

Q. There are a good many cities which have dealt successfully with that problem, are there not?

A. In the case of relatively small cities, there are quite a number. There are some fairly large cities that have met with some substantial success; but I do not believe it is at all feasible to cut the consumption of water in our large American cities, get it reduced to anything like the low figures which one reads of for cities of corresponding size in Europe. That is the habits of the American people are fixed in a way that it is not at all easy to reconstruct them.

Q. When you got 300 gallons per capita, did you consider the floating population, or did you take only the resident population of the city?

A. That is the resident population as I recall.

Q. Only?

A. Only.

Q. But in the figures you have given, you include the floating population of 300,000 with the same value per capita. I think you characterized that as a margin of safety?

A. That applies only to the loop and West Side district, as that was taken into account in the factor of safety as I described it day before yesterday. The rated population obtained by adding the sum of all of these different projects together does not take into account the floating population.

Q. Have you any idea what difference it would make in your figures if you assumed a per capita consumption of 100 gallons instead of 300?

A. No, I have no relative figures in mind. I don't think it would affect the cost of the sprinkling filters appreciably, but it would affect the cost of the settling tanks, of the intercepting sewers and of the pumping stations, and the operation of the pumping stations. It is too big a proposition for me to speak about in comparative figures in an offhand way.

Q. It would be considerable, would it not?

A. It would be quite an amount of money, yes, that would be involved.

Q. A good many millions of dollars?

A. It would be several million. I don't know how many.

Q. In your 1906 report, you were figuring on the basis of 150 gallons per capita, were you not?

A. For the Calumet District, the 1906 report dealt with

the flow of sewage assumed to come from a system of separate or sanitary sewers only; and not dealing in any way with any first flushings or combined sewers, due to rain water. The 150 gallons per capita which you mentioned is the approximate figure, as I recall it, taking into account some allowance for ground water entering the sewers through the joints in the sewers.

Q. Why would the cost of the sprinklers not be reduced if the per capita consumption were cut down from 300 to 100 gallons?

A. Because the facts show, as I understand them, that the rating of sprinkling filters in a point of capacity depends upon the number of units or the quantity of organic matter reaching the sprinkling filters rather than the volume of sewage. That is shown very clearly by comparing the results obtained from operating sprinkling filters in this country as compared with European experiences. In America, with our dilute sewage, sprinkling filters can be operated successfully at rates two or three times as great as is the case in Europe. But when the work of the two plants in America and Europe are compared on a per capita basis, then it is found that the experiences are quite similar, so I do not believe that the reduction in the volume of flow for a given population would have any substantial influence upon the area of sprinkling filters required.

Q. There are other factors that enter into that that might have influence, are there not?

A. There are some other factors, but that does not influence the correctness of this general statement which I have made, namely, that it is the units of organic matter which control rather than the volume of applied sewage as regards rating of sprinkling filters.

Q. Are you prepared to say, as an engineer, Mr. Fuller, that there could not be devised a system of dealing with this question on the basis of a diversion from Lake Michigan of 4,167 cubic feet per second, which, so far as the protection of the water supply of Chicago is concerned, would give as good results as were had in the year 1906 in Chicago, at a much less expense than your project A?

A. I have not given specific study to the 1906 conditions, because those related to the present project carried out only to a partial extent. I believe that these projects which I have described are as economical as can be devised to give safety to the Chicago water supply approximating that which would be obtained with a complete diversion of all Chicago sewage

from Lake Michigan. It is this latter proposition which I have considered rather than an attempt to figure projects against the dilution method as now applied, in its unfinished and partially applied stage.

Q. Your answer to the question would be the same if I asked you with reference to the years 1907 and 1908, would it?

A. Precisely the same.

Re-direct Examination by Mr. Adcock.

Q. Is it your understanding, Mr. Fuller, that the capacity or the dry weather flow was obtained from actual gagings of the sewers; is that the way you arrived at that figure, present experience?

A. Yes, either gagings of the sewage or the volume of water and sewage that is pumped, ground water and sewage that is pumped at 39th street station.

Q. Have you any idea of the cost of metering the water supply for a city like Chicago; would it be expensive or not?

A. Yes, it would run into a good many millions of dollars. I don't know precisely how much.

Mr. Wilkerson: That is on that metering, there would be just the one cost for the installation of the meters in the first instance.

A. And the fittings, cost of reading the meters subsequently at frequent intervals.

Mr. Adcock: Would there be some cost of maintenance of the meters?

A. Yes.

Q. There was some reference made to the Hering & Fuller report of 1906, to the International Waterways Commission, where you discussed the rate of dilution. Have you anything further to say with reference to that statement and also the statement which was made by Mr. Hering in his report to Mr. McCormick of 1907, in connection with any subsequent data that you have obtained?

A. I have looked over all these lines of evidence that would bear on the adequacy of the legal minimum rate of dilution of the Chicago sewage, by the water flowing down the main channel. In the Hering and Fuller report of 1906, printed in 1907 as War Department Document number 293, there is found on page 46 the following paragraph representing a careful study of the conditions found at that time. I will read as follows:

"It is our judgment that for large canals, with the trade wastes eliminated, a dilution of 3.33 cubic feet per second for each 1,000 population connected with the sewers, also re-

ceiving storm water, is as low a figure as it is now possible to state. Local conditions, especially temperature, which affects bacterial activities and the coefficient of absorption of oxygen by water and still other matters bear upon this question, the detailed discussion of which is not now necessary. We feel certain that a dilution of 2½ cubic feet per second would cause offense at times, and probably also a dilution of 3 cubic feet per second."

I might add further that at the time Mr. Hering recorded his single observation in the Autumn of 1907, there had not been obtained an extended series of observations made in fact for days and weeks at a time at 12-hour intervals of the dissolved oxygen content of the mixed lake water and sewage, as it flowed down the main channel.

I have, since preparing my portion of this report in 1906, given very careful study, not only to the dissolved oxygen records of the canal water, but I have also visited the main channel during the warmer season of the year, and studied various records and observations, and feel that the statement made in my direct examination, namely, that 3½ cubic feet of diluting water per thousand population is as low or small a diluting factor as it is reasonable to assume now. In fact, as I then stated on direct examination, if any change were to be made in the legal minimum ratio of dilution, it is my judgment that the volume of diluting water should be increased rather than decreased.

Q. You referred to the oscillations of the lake due to winds affecting the flow in the channel, and danger of reversal of the flow of the Chicago River, that is, towards the lake. Have you anything further to say with reference to that subject?

A. I looked into that matter with considerable care in 1906 and have given it some thought during the current year. I have not recently made a study of the detailed records, but I did look into that matter in earlier years. I find in this same War Department Document Number 293 a statement of what I had in mind while I was being cross-examined on day before yesterday. On page 7, paragraph 22, there is a statement as follows:

"Variation in the level of the lake's surface due to winds and to change of barometric pressure are frequent and irregular, and at times violent. Variations of more than six inches are very common, often occuring hourly for many hours in succession, while variations of two or three feet within an hour are not uncommon."

Q. Some mention was made of possible pollution of the water supply as the result of sewage or waste coming from ships or boats in the vicinity of Chicago? Have you anything to say as to how that pollution might be removed or prevented so as to make it unnecessary to use any other means to purify the water, or filter it or protect the water supply?

A. I have given some consideration to the prevention of the polluting influence of shipping upon the Chicago water supply, under conditions where all local sewage from the land population were diverted from the lake. I think I stated in my cross-examination that federal, state and municipal regulations, if properly applied, could bring about a discontinuance of this element related to the hygienic quality of the Chicago water supply. Whether it should be federal legislation, under federal supervision, or state or municipal control are points upon which I have not come to a final conclusion, but I should suppose that with the interstate factors involved it would be the federal legislation and control that would be of perhaps the greatest assistance. Whether the local laws would allow state or municipal control to be effective is a matter upon which I am not fully informed.

Q. What I had reference to was more in particular the mechanical means that might be adopted, that is the closing of the closets of the ships within a certain distance of Chicago, would that have any effect?

A. Yes, that is what I had in mind and assumed to be the feature that was to be taken care of in answering the last question. It would mean paralleling somewhat the practices of railroad transportation in closing the water closets and keeping them closed on these various vessels until they had passed beyond certain distances removed from the intakes of the Chicago water supply.

Q. Would it be possible for the boats to be provided with receptacles to retain the excreta that might be accumulated at certain times while they were in the Chicago Harbor or within certain distances of the Chicago Harbor, and then to be dumped at points outside of certain zones?

A. Yes, that would be feasible.

Re-cross Examination by Mr. Wilkerson.

Q. Having in mind the condition of the canal as described on page 8 of the report of Mr. George M. Wisner, the chief engineer of the Sanitary District, as follows: "At present there is a large deposit of sludge in the fore bay of the power house, extending from two miles north to the controlling works and into the rock section. This is due to the greater cross-section at that point and the tendency of the controlling works to act as skimming devices holding back the settling or suspended matter. In the rock section there is a little settled matter, slight sludge deposits being found on the sides. In the full size section from Willow Springs to Summit, there is a sludge deposit from which arises at times a very noticeable gas ebullition. This deposit is due to the reduced velocity in the large cross-section. The deposit generally seems to be a fine silt containing a small amount of organic matter similar to the grit that is found in the grit chamber of the 39th street pumping station," is it not your opinion that even though a diversion of say 10,000 cubic feet per second is permitted to be made from Lake Michigan, it is only a matter of a few years, in view of the growth of the population of Chicago, when with that diversion it will be necessary for sedimentation tanks to be constructed and other devices used to treat the sewage, and for aeration, perhaps to be employed to eliminate the offensive conditions that are there described?

A. No, I don't think that that is true so far as elimination of these sludge deposits in the fore bay of the power house or in the main channel is concerned. In fact, as the population grows and the volume of diluting water is increased, it will naturally increase the velocity of flow and lessen the deposit of sludge. The accumulations of sludge do not at the present time seem to produce conditions that are in my mind offensive as sewage disposal projects go. That is to say the amount of fresh sludge in this accumulation perhaps of years is not great enough to give off offensive odors that are noticeable a long distance away. It is true that there is some gas ebullition showing that the actual diluting factors employed are not excessive, and perhaps it may tend to show that they were rather too small under some circumstances. These deposits, however, are a function of velocity of flow essentially.

Now, coming to the question of what might happen in 1920 or later on, I can see where the population might reach

a point where the economic ratio of dilution, the capacity of the channel might become such that some supplementary treatment might ultimately be required. I mean by that treatment of the sewage other than by dilution.

Q. It is your opinion, then, at the present time there is no objection to putting raw sewage direct into the canal?

A. As a general proposition I consider that is true. I believe, however, that with increasing velocities there would be a lessening of these deposits of sludge, but on the other hand with a reduction in the volume of lake water to say 4,167, the accumulation of sludge would clearly become much greater, and offensive conditions would increase very markedly.

Q. Well, there is not much room for increasing velocity, is there, between the amount they are now taking out, if it is 8,000 cubic feet a second and 10,000 cubic feet?

A. Why, I should say there was quite a little in percentages; from 8,000 to 10,000 would be an increase of 25 per cent.

Q. Would not make much difference in the sludge deposit?

Mr. Adcock: You are assuming for the purpose of that question that we are taking 8,000 cubic feet?

Mr. Wilkerson: I understood you to say the other day that you were.

Mr. Adcock: No, I do not think it is that amount.

Mr. Wilkerson: Of course that is a matter for your answer. We haven't got your figures yet, but it has been my understanding to be admitted in this case that you were taking from seven to eight thousand feet.

Mr. Adcock: Whatever we are taking of course we will admit. But I do not understand the figure reaches that point.

Adjourned subject to notice.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the rooms of the Sanitary District, Chicago, Friday, December 12th, 1913, 10:30 A. M

Appearances:
Mr. James H. Wilkerson and
Mr. Albert L. Hopkins,
Representing the Government.
Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
Representing the Sanitary District.

ASA E. PHILLIPS, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your name?
A. Asa E. Phillips.
Q. Where do you reside?
A. Washington, D. C.
Q. What is your age?
A. 47.
Q. What is your occupation?
A. Civil engineer.
Q. Will you state what, if any, experience you have had either as civil engineer or in connection with any sewerage disposal plants, and what if any training and education along those lines you have had?
A. I graduated in civil engineering at Lehigh University I have been engaged in sanitary engineering work continuously for more than 20 years. I have made a study particularly of sewerage, and of sewage disposal work in this country; covering experience along the Atlantic seaboard particularly—the large cities.

I have visited the sewerage works of a number of the large European cities, among which are London and Paris, and Birmingham and Manchester in England.

I have had charge of the preparation of the plans, of the construction and of the operation of the sewage disposal system of the District of Columbia, covering a period of more than 14 years past.

I have been, for the past seven years, superintendent of the sewer department of the District of Columbia, having charge of all sewerage works.

I have studied the modern development of sewage treatment, and the appliances that have been developed up to date for artificial disposal of sewage.

I have had some connections with several small projects; and also have been connected, in an advisory way to some extent, with the Passaic Valley work for the sewage disposal project for the drainage in the Passaic Valley.

Q. In other words, you have made a study, in the last 20 odd years, of sewage disposal, both from the scientific and practical viewpoint?

A. Yes.

Q. And what has been your work?

A. That has been my work, the practical construction and the practical operation of the works during that period.

Q. What is your present occupation?

A. Superintendent of the sewer department of the District of Columbia.

Q. How long have you occupied that position?

A. The past seven years.

Q. And prior to that time, what position did you hold?

A. Prior to that time, I was engineer in charge of the plans and construction of the sewage disposal system, for about seven years.

Q. What are your duties as superintendent of sewerage of the City of Washington?

A. In our organization, the superintendent of the sewer department is the engineer for the department; has charge of the preparation of plans for construction, the actual construction work, the maintenance and operation of the works; and the studies, of course, for new works and preparation of estimates for the department of construction.

Q. And what were your duties in the position which you held formerly, that is, prior to the present position?

A. I was engineer in charge of the sewage disposal system.

Q. What did you have to do in that connection?

A. I had the preparation of the detailed plans, the letting of the contracts, the construction work, and the design of the works, the stations and the various works connected with the plan.

Q. How were you appointed to the position, if it was an appointment?

A. I was appointed to the position by the Commissioners of the District of Columbia.

Q. Who are they?

A. The Commissioners of the District of Columbia are

a body of three men appointed by the president and confirmed by the Senate, one of whom must under the law be an officer of the Corps of Engineers of the army, and the other two are civilian commissioners. They must have had a residence prior to appointment within the district.

Q. What are their duties, just in a general way?

A. They fill the office of mayor, council and all the governing bodies of the ordinary city organization.

Q. You have certain works there at Washington for the disposal of sewage, do you Mr. Phillips?

A. Yes, we have what is known as the sewage disposal system of the District of Columbia, which is a separate construction, really an organization apart from the sewerage system itself. It was appropriated for specially, specifically by Congress, and its maintenance is provided for under separate appropriation, although its control and operation are under the same office.

Q. Will you describe those disposal works?

A. The disposal works provide for the collection of the sewage from the various public sewers of the city, and the delivery to a pumping station, required on account of the very flat, low level of the city, in the older part and along the river fronts. It is passed through the ordinary rough treatment preliminary to disposal by dilution at the station and elevated sufficiently by sewage pumps to discharge into the river at submerged outlets below the city in about midchannel of the Potomac River.

Q. Is the method which is used there known as the dilution method of disposal of sewage?

A. It is absolutely the dilution method.

Q. Where is the sewage discharged into the Potomac?

A. It is discharged into the Potomac at the bottom of about midchannel, four miles below the city.

Q. Is the sewage treated in any way to improve it, or purify it?

A. No.

Q. What is the treatment that is given the sewage before it is discharged into the Potomac?

A. Well, it passes through a grit chamber, and through screens, coarse screens; through a skimming tank where the grease is removed.

Q. What is the purpose of that?

A. The purpose of that is to avoid the creation of any nuisance on the river surface at the point of outfall. Owing to the rather restricted territory, to keep our construction

within the District of Columbia it was necessary to locate the outfall almost opposite the City of Alexandria, Virginia; and it was desirable to have the discharge into the river at that point such that it would not be subject to criticism and objection on the part of the people of the City of Alexandria.

Q. Does it improve the sewage so that it requires less water to dilute it, or do those works merely take out the solids so that the sewage when it is discharged will not appear so unsightly?

A. The work that is done on the sewage before the discharge does not affect at all the quantity of water required for dilution. It is merely to avoid unsightly conditions that would be objectionable; and to remove heavy material that might be an element of objection in operation, owing to the fact that we have to discharge from our pumps through inverted castiron siphons laid very deep below the channel of the Anacostia River, rising again on the other side, so as to prevent obstruction in those pipes.

Q. Do you pump all the sewage, including the storm water, through these interceptors?

A. No, we pump only the sewage, and in part the first runoff of storm water. Of course we pump the light rains, but ordinarily the storm water discharges at the various outlets along the city front. I might say in that connection, if I may, that the reason for the arrangement, the reason for selecting the location of the outfall so far below the city is the fact that Washington is at the head of the tide in the Potomac, with two substantially blind channels that have no flow of water normally through them; and it is desirable not to have the sewage discharged where it would back into those slips, such as the Washington channel, for example, and the channel of the Anacostia River, leading to the Navy Yard.

The point was selected with the view that the incoming tide would not carry the sewage from the point of outfall into these blind channels along the water front of the city.

Q. Who laid out the plans or recommended the method of taking care of the sewage, which has been adopted there at Washington?

A. The recommendations were made by a Board of Sanitary Engineers appointed by President Harrison in 1889, consisting of Mr. Rudolph Hering, Mr. Frederic P. Stearns, and Mr. Samuel M. Gray. They made a report the following year outlining a recommended plan for the disposal of the sewage

of the city, which has been carried out substantially, and has been in operation for the past seven years.

Q. How long did it take to install those works there, from the time that the money was provided for by Congress?

A. The report was made in 1890. The first appropriation was made by Congress in 1893; consecutive and continuous appropriations began in 1900 and the works were completed near the beginning of the year 1907.

Q. What did they cost?

A. The total cost of the works was substantially $5,000,-000.

Q. What is the water supply for the City of Washington?

A. Washington takes its water supply from the Potomac River at Great Falls, sixteen miles above the city, through a conduit laid in 1858. It passes through one large reservoid untilized as a settling basin; then to a receiving reservoir at the westerly limits of the city; then through a deep tunnel to a reservoir and purification works, at the north end of the city near Howard University, where they have a modern slow sand filtration plant.

Q. When was that filter plant installed?

A. That filter plant was installed about six years ago, possibly about 7 years ago.

Q. Is that a modern plant?

A. That is a modern plant.

Q. How does it compare with other filtering works?

A. It is a slow sand treatment, of probably as high class as any in the country, and very efficiently maintained. The quality of the water is perhaps as high as the water supply for any city in the country, of any considerable size at any rate.

Q. That is, where filters are used?

A. Yes, where filters are used.

Q. Is this water in the Potomac polluted in any way above the intake, by sewage being discharged from other cities?

A. It receives a considerable pollution from towns in Maryland, such as Cumberland, Maryland; also from towns in the Shenandoah Valley in Virginia. All the pollution is at a considerable distance from the city. For example, Cumberland, the largest town in the basin, is 180 miles from Washington.

In addition to the pollution, the Potomac carries a very heavy amount of silt which always rendered the water objectionable for domestic use. It is turbid water.

Q. Do you know to what extent the artificial methods for

the disposal of sewage, so-called, purification of sewage are used in the United States to-day, in the larger cities?

A. In connection with the work at Washington and the development of the sewage disposal system, I have kept in close touch with the feature of treatment works and their development in the country, and attempted to follow the operation of those works, as to the success of operation.

Q. How largely are these treatment works used in cities of the United States, as compared with the dilution method of sewage disposal?

A. In a broad sense, they are not used. In the cities of the first class, something like 18 cities over 300,000 people, the disposal of sewage is entirely by dilution, with the one exception of Baltimore which has recently completed a plant, but has only partly operated same to date.

In the cities of the second class, perhaps 14 cities over 150,000 population and less than 300,000, we have treatment works at Providence, Rhode Island, at Columbus, Ohio, and at Worcester, Massachusetts.

In the third class cities, coming up from 100,000, we have treatment works at Atlanta.

Q. What is the purpose of these purification works as used in these various cities?

A. They have a somewhat varying purpose. Altogether, their object is to prevent nuisance in the streams in which they discharge. The variation from that is in the two cases, one, of the older works at Providence, Rhode Island, were put in with a view of preventing the oyster beds in the Providence River below the point of discharge from being polluted, and in the case of Baltimore, comparatively new works, to protect the oyster beds in the upper Chesapeake Bay from pollution.

Looked at from the point of view of practical results up to date, none of these works have accomplished what would reasonably be supposed to be their complete function. In every case, they discharge either an effluent that does not have a degree of purification such as to prevent the streams from actual and dangerous pollution, or they operate intermittently, and intermittently throw a load of sewage directly into the streams, or discharge the sludge from the treatment works at times into the streams.

In the comparison between what is accomplished at these works and what is accomplished at other works using the method of dilution where reasonably uniform and constant results are obtained, practically unchangeable except due to the

variation of season and of temperature, these artificial treatment works have not been successful. Some qualification ought to be made as to this, in the case of the new works at Baltimore which, while completely contructed, handle only a very small portion of the sewage, and with regard to these works they have developed just as the works at Providence developed, very serious local nuisances, which are involving lawsuits. And at Baltimore, a very great reliance, even by the engineers in planning the works, has been placed in the effectiveness of the purification by dilution, that would be accomplished in the travel through the arm of the Bay in which they discharge, Back River, of some fifteen miles before reaching the oyster beds.

In the case of the other works, having only in view the prevention of the gross pollution of small streams, such as the new works at Atlanta, there is no very serious problem such as the protection of the water supply, involved.

The works at Providence, chemical precipitation works, designed to protect the oyster beds from pollution, have been substantially abandoned, and the works there to-day, with the exception of some sedimentation and some attempt to disinfect the sewage, are substantially, pure and simple, works of dilution.

Q. What can you say as to whether the artificial methods that are suggested for the purification of sewage will be used in the future for any great length of time?

A. In considering that phase of the question, the abandonment of older processes, though comparatively new themselves, and the fact that the present appliances that have been introduced in the design of artificial treatment works are extraordinarily new, and might fairly be considered experimental, it is a reasonable conclusion that with the changes that have been going on in a short space of a little more than 15 years, and most of it in the space of a little more than 5 years, possibly within 10 years, there will be new lines in the treatment of sewage, and new processes that will revolutionize as completely the methods of to-day as those methods were revolutionized only a very few years ago.

Q. In solving the problem or determining the plan of disposal of sewage, what elements are taken into consideration by sanitary engineers, particularly with reference to the adoption of a plan which will be a safe and sure plan for protecting the water supply?

A. The very first consideration in weighing various possible plans in any case would be the protection of the water

supply. The absolute necessity of this exists where a water supply is in reasonable proximity to the works. That is in the discharge, for example, of the effluent of artificial works or of sewage for dilution within a certain range of distance subjects the water supply to pollution and to serious injury. At greater distances, further removed, of course, that becomes less important. In any case, the method should be such and the design of the works such as to absolutely prevent at any time the pollution of the water supply if that is within the range of possibility; that is even the contingency of pollution should be prevented.

Q. That is when you say pollution, do you refer to pollution that may be accomplished by the discharge of raw sewage, or any effluent from these so-called purification works that you have mentioned?

A. I mean both, and it involves both the raw sewage and the effluent because there is no, absolutely no certainty that with the most modern works, most carefully devised and designed, that there will not be periods when raw sewage may be discharged.

And then, on the other hand, is the question of the efficiency of the works themselves in obtaining, if it is possible to obtain such a thing, an effluent that is entirely, at all times, free from dangerous pollution.

Q. Then, as I understand it, Mr. Phillips, you give considerable weight to the danger which may result from the operation, that is, the inefficient operation of these plants, disposal plants, or the efficient operation of filter plants to filter water supply?

A. A very great deal of weight, owing to the absolute uncertainty of continuous, efficient operation in both cases.

Q. Take it in a large city like Chicago, what are the difficulties necessarily to be encountered in the use of artificial methods of sewage disposal?

A. The greatest difficulty is involved in the impracticability of handling the sewage otherwise than on a system of units, owing to the enormous volume of sewage, to the great areas covered, and the long period of time involved for the transit of the sewage to the treatment works. It involves the necessity of the construction of such works substantially within the city close to dwellings; that is in fairly close proximity to dwellings; and all experience on the treatment of sewage to-day, so far as the location of treatment works is concerned, is in favor of their remote removal.

Baltimore, for example, one of the newest, and the largest

city in America to put in treatment works, located the works something like seven or eight miles from the city, selecting a location remote from any dwellings. In addition to that, they felt compelled to buy large tracts of ground to create a neutral zone around their works, and yet, with a very short period of operation, and very low load on their works, only having part of the sewage to handle, they have been confronted with damage suits for the creation of a nuisance, by the owners of property along their holdings. The certainty in a very large community of the sewage reaching the works stale, its creating local nuisances along the line of travel in the interceptors, even with the entire area broken up into districts, is a great problem and a source of danger in a very large community.

The difficulty of handling the resulting materials accumulated, the sludge particularly, from the treatment works, its removal, its necessary storage in preparation for its removal, appears to me to be a most serious problem in considering any treatment works for very large communities.

Q. In the last three years, what has been the death rate in the City of Washington from typhoid fever?

A. In the years 1910, 1911 and 1912, the death rate from typhoid in Washington was 24, 22 and 22, respectively; per 100,000 population.

Q. Have you the death rate in the City of Chicago for those years?

A. Yes, apparently the death rate in the City of Chicago for the years 1910, '11 and '12, was 14, 11 and 8, respectively.

Q. As I understand it, Mr. Phillips, you had to do with the details of building these works at Washington City, that you mentioned?

A. Yes, I had charge of their construction.

Q. And you have had charge of the operation since?

A. I have had charge of the operation continuously, since they were put into service.

Q. If I remember correctly, you stated that you operated pumping works there?

A. Yes.

Q. Now, in your experience in the operation of those pumping works, would you consider that the estimate of $350 made by Mr. Fuller per water horse power per year a reasonable estimate for the cost of operating pumping plants?

Mr. Wilkerson: I will object to that, on the ground the witness is asked to state an improper conclusion; without a proper basis. I do not object to the form of the question, but I object to the statement of the conclusion?

A. After seven years' experience in the operation of the pumping plant at Washington, and a close study of the cost of pumping, considering the elements that necessarily enter into an estimate, covering a period of a number of years, I would consider the estimate of $350 per water horse power per year reasonable.

Cross-Examination by Mr. Wilkerson.

Q. You have had nothing to do, as I understand you, with the construction of the works at Washington relating to the water supply?

A. I have not; no.

Q. You do not know what those works have cost, except by hearsay?

A. Except by seeing the reports that are made each year.

Q. I think it is in the record, but if you know I would like to have you tell us how much the works for filtering the water supply of Washington and furnishing the water supply, cost the city in the aggregate?

Mr. Austrian: You mean the cost of the works themselves?

Mr. Wilkerson: Yes.

A. I cannot give the figure—you mean of the filtration plant alone, or of all the works?

Q. I mean of that part of the plant which is necessary for the filtering of the water; that is of the part of the plant which does the work which would not be done if the water were taken directly from the river?

A. Well, Washington is peculiarly governed, and it is a very complicated proposition, owing to the fact that the works beginning at Great Falls on the Potomac, passing through the conduits to the reservoirs, to the filtration plant, are directly under the Chief of Engineers of the Army; and the pumping station and the distributing works come under an entirely different organization; coming under the District Commissioners.

Q. Have you any idea what the total cost of that plant has been?

A. The total cost of the entire plant?

Q. Yes?

A. I think the total cost of the entire plant has been about $16,000,000, but that involves all costs going back to the construction of the original conduit from Great Falls, various modifications that have been made and changes that have

been made in the works, and represents really the total aggregate capital invested.

Q. Do you know how much has been spent on these sewage works?

A. In the District of Columbia?

Q. Yes?

A. The total cost of the sewerage system, and of the sewage disposal system for the District of Columbia, involving all investments that have been made from the beginning of the city, including all the lateral system of sewers, has been substantially the same amount, about $17,000,000.

Q. The reason why Baltimore does not use the dilution method, or has discontinued the use of the dilution method, as I understand you is to protect the oyster beds?

A. No, primarily the reason for the construction of the Baltimore sewerage system—and it has been frequently stated it did not have a sewerage system before, when as a matter of fact they did; they discharged very large quantities of sewage into the very small harbor there at Baltimore, which was very seriously polluted. Some parts of the city did not have a developed sewerage system. The proposition was to provide a main sewerage system, and to prevent the pollution of the harbor, which was very narrow and small, and had practically no circulation of water. It became a septic tank, really. The odors were very great.

Q. It was at Providence they were protecting the oyster beds?

A. Yes, in both cases the question of protecting the oyster beds was involved immediately; at Baltimore when the study was begun for the sewerage system; and for the removal of the sewage from the harbor by a disposal system, but the matter of the protection of the oyster beds near Baltimore was determined, not so much as an engineering matter pure and simple, but by an absolute act of the state legislature, which required it.

Q. Have you had occasion to make a study of the sewage disposal problem in any cities where the question has been that of increasing the use which may be made of a limited quantity of water, in handling the sewage by the dilution method?

A. I know of no city to which that applies except Chicago.

Q. I say, you know of no city with a river, where the attempt either has been made, or where the matter is under

consideration, or partially purifying the sewage before it is discharged?

A. Oh, yes, that has been under consideration in perhaps most of the larger cities, in one form or another, as an ultimate proposition.

Q. Of the partial purification of the sewage?

A. Yes. That of course is a subject that we consider. We are studying at this time at Washington that question, not as anything immediate, but as possibly a subject that will be of interest when the population has reached a far higher figure than the present.

Q. What is the outflow of the Potomac River?

A. It has a minimum flow of record of 900 second feet.

Q. What is the average flow?

A. That is the minimum of record, about 900 second feet. It has during the fiscal year 1913, ending June 30, 1913, a minimum range of flow, in and around 2,000 second feet. That was about the minimum of that year, which was a very favorable year. We frequently have a minimum as low as 1,200 second feet for one day, or 1,400 second feet. It varies very much, depending on the rainfall and distribution of rainfall.

The average flow would always exceed 2,000 second feet; probably covering any period of years the average flow would be very much in excess of that. The minimum might vary, ordinarily we could say, between 2,000 and 2,500 second feet.

Q. A flow of 900 second feet would take care of the sewage of how large a population by the dilution method, as you understand it?

Mr. Austrian: In what sort of a body of water?

Mr. Wilkerson: In the Potomac River.

A. It would take care of a pretty small population. You have to remember that 900 second feet is a question of a day, the flow drops down to that and immediately lifts out of it.

Q. Well, a flow of 2,000 second feet would take care of how much, according to your understanding of this subject, by the dilution method, flow of the Potomac River.

A. Well, probably I could best answer that by the statement of the Board of Engineers reporting on the sewage disposal system, stating that the method was adequate for a population of 500,000 people.

Q. 500,000. And when the population reaches 500,000, you will be confronted with the necessity of a partial purification of the sewage before it is discharged into the river?

A. Well, possibly not at 500,000, but there is a limit there.

We have probably some difference of opinion on that as to exactly what the population would be when that must be considered, but that is of course the pending thing.

Q. What in your opinion will be the population of Washington when it will be necessary to partially purify the sewage before it is discharged into the Potomac?

A. My opinion is that the limit may be reached when the population reaches 750,000 people. It would have to be explained in reference to the amount of water for dilution that the local situation is very peculiar. The sewage is discharged, not into a running stream or into a lake, but is discharged into the upper reach of a tidal river, where we have a very large drainage area and a large storage basin. In our study of the work, we speak of that stretch of the river as the dilution basin and into this the upland water flows.

Now, we have a river discharge up to 250,000 second feet. We have about three billion cubic feet of water in this range of river as a storage. When the flow is running along up to 5,000 second feet every day, and then goes to four and drops down to the low limit, it is generally a quick drop-off and back again. The low limits are longer in period, but the very high limits are short periods constantly recurring so that while they do not increase so markedly the average second foot flow of the river, they do by their piston effect in displacing the entire immense storage of water with comparatively clear pure water from the upland flow, provide additional capacity for dilution.

Q. There are those who think that the limit will be reached at 500,000 people?

A. That was stated in the report of the Board. That should be qualified in another way, that it was stated at a time when the regular and consistent gaging of the river was not carried on, and it was based on such data as was accumulated in connection with the data of the water supply system at Great Falls where the record was kept more consistently of the extreme low flow of the river, instead of a constant daily reading, and a determination of what the real capacity of the river was.

Q. Assume a gradual growth of population of the city of Washington, so that it would have a population of 2,000,000 within 20 or 30 years, what would have to be done with that sewage disposal plant?

A. There would have to be some facilities for the sewage treatment introduced.

Q. That is there would have to be a partial purification of it, before it was discharged into the Potomac River?

A. Yes.

Q. And that is inevitable in Washington when the population passes a point some place between 500,000 and 750,000, in your opinion?

A. Yes, not between 500,000 and 750,000. I would say the point of when consideration should be given to it is at 750,000. I think I stated that, that was my intent, but the commission had stated it would be adequate for 500,000. I suppose they may have dealt rather conservatively with their figures.

The question of that treatment, however, of course would be a matter of development; and that question of development is one that we are, even today, considering. We have a large area geographically, 70 square miles; that is large among the municipalities in the country, about the fourth, I think, largest in the country; and that problem involves the development of the system in detail in advance, in anticipation of the need, by the construction of separate and storm water sewers, the elimination for the further reach of population of combined sewers, and an installation and construction and design of a sewerage system that would be in form to permit the treatment of the sewage of the excess population. And I think beyond all question, merely considering the development of sewage disposal works today that that will be—that is without any idea of the future improvements, and we have had a tremendous lot of changes in a very short time—that that will be the way in which the problem will be worked out.

Q. This art is one in which very rapid progress is being made, is it not?

A. And very sudden changes.

Q. Very sudden changes?

A. Yes, sir. The great works, thought to be great works at Providence, became a back number in such a short time, that they were started in 1900 and today they are so much out of date that they are antiques.

Q. You have given some study to this question of the partial purification of sewage have you not?

A. Yes.

Q. It is done in some cities with success, is it not? I am speaking of the partial purification so as to increase the use which may be made of a limited amount of water?

A. I don't know of a city in which it is being successfully done.

Q. You say you know of no city in which it is being done successfully, or no city in which it is being done at all?

A. I mean a city; I mean for instance in the classification of cities I gave of the first class, over 300,000 people. In a very small community, of a house or two houses, a village or small towns, even a small city, there is a great deal of possibility in that direction, and of course we have some examples.

Q. I should think a place like Indianapolis would have that question to deal with sooner or later. What is the outflow of the river there, do you know?

A. I do not. I do not recall the figures for Indianapolis.

Q. I should think cities on small rivers of that kind would have that problem sooner or later, would they not?

A. Yes, no question about it. And it is a problem that awaits them.

Q. If all the solid substances were screened out of the sewage, by what amount is the quantity of water required for dilution purposes diminished in your judgment?

A. In my judgment the volume of water required for dilution is very little changed.

Q. By screening?

A. By screening, and by the ordinary coarse sedimentation. It is a function of the capacity of the water and of its oxygen content to accomplish the purification. The quantity to be purified is the quantity of organic matter which is not sensibly removed, either by screening or by the ordinary coarse sedimentation such as for instance we have in Washington.

Q. It is increased some by screening and sedimentation, at least that is the view of a great many engineers, is it not?

A. Of course you must define first the screening and then the sedimentation. If you go into treatment works sedimentation, of course you are removing a larger quantity than you are from the grit chamber sedimentation that is ordinarily practiced, such as we have. In screening, if you take the very fine meshed screens, you are removing a portion of the organic matter, but you are not removing a very great proportion, and you are not affecting the purification of the sewage to any great extent. You still have to deal with sewage containing comparatively the same amount of organic matter that will require substantially the same volume of oxygen

from the water of dilution, and therefore substantially the same volume of water for dilution.

Mr. Adcock: You mean the volume of water containing an oxygen content?

A. Yes.

Q. Are you familiar with the views of Mr. Hering on the subject of increasing the use to which the water may be put by the partial purification of sewage?

A. Yes, I have talked to him some about that and read—

Q. You have read what he has written?

A. Read what he has written.

Q. You and he agree on that substantially, do you, or do you think he is wrong?

A. Well, that is a question of judgment as to what can be accomplished.

Q. You are rather conservative on that?

A. I am very conservative on that. On treatment works, I have to be shown; I have not seen them.

Q. You think Mr. Hering is a little radical about the things he thinks can be accomplished by this partial purification?

A. I think he probably is taking a hopeful view of it.

Q. You are rather pessimistic about it?

A. I am inclined to be conservative.

Q. You say that in the problem of sewage disposal, you regard it as of great importance to keep the sewage away from the source of the water supply. I think that was your statement?

A. Yes.

Q. If as a matter of fact the conditions are such that even without the discharge of the sewage into the water it would be necessary to filter the water, that would not be a matter of so much importance would it?

A. I would yet consider it a matter of very great importance.

Q. Even though the conditions were such that they made it necessary to filter the water?

A. Yes. I think that the sound point of view is to prevent the pollution, first of all.

Q. What is the object of preventing the pollution of water that is already polluted? I think you understand my question, do you not?

A. I do not.

Q. I say assuming that the condition of the water is such that it is necessary to filter it before it can be used for drink-

ing purposes, why is it a matter of so much importance to prevent its further pollution, in your opinion?

A. Well, as I stated, all possible pollution should be prevented, first of all. That is the first safeguard of the water supply. If there is some pollution, it would not justify ignoring opportunities to prevent further pollution. That is what I attempted to say.

Q. Well, let us take the case of Lake Michigan for instance. Suppose for example the sewage of half of Chicago is discharged into the lake so that it became necessary to filter the water before it was used for drinking purposes. The impurities in the water would be removed by the filtering process just the same if the sewage of all the city were discharged into it as if the sewage of half the city were discharged into it, would it not?

A. Absolutely not, for the reason that you must furnish a consistent, uniform, invariable quality of water. All the typhoid outbreaks we have had, the epidemics we have had, have not been due to a consistent moderate pollution, but they have been due to the breaks that have come, and those breaks you might encounter in your filter plant itself. Is it an absolute assurance of an unpolluted water supply? I mean after treatment, does the treatment ensure at all times, under all conditions, what is essential for the community?

Q. Yes, I think I understand those general observations; but I still am unable to see—and I do not want to argue with you, but I would like to get your further view on this—I am still unable to see why the filtering process, if it is necessary at all, will not take care of the impurities which would come from discharging all the sewage into a body of water as well as it would if the sewage of only half of the population was discharged into the body of water; that is to say if you must filter the water anyway?

A. Simply because every pollution, every part of the pollution, every increment of pollution rather, is an increased load put upon the purification works; and is an increased opportunity for any break in the absolute efficient operation of those works.

Q. Well, applying that rule then, cities along the banks of rivers should not be allowed to discharge their sewage into the river, because of the effect upon the cities further down?

A. Well, that is not quite a parallel case, because this process of purification by dilution requires a certain space of time and distance. The distance, really, in the case of the

river, is merely an element of time substantially, but it can be reduced into a statement of distance, and so a city putting sewage into a river at a point 200 miles or 300 miles away from where a city further down the river takes its water supply is not in the same relation at all to the case that you were speaking of, of Chicago putting its sewage directly into the lake and immediately taking its water supply from a reasonable proximity out of the lake.

Q. What do you mean by a reasonable proximity?

A. As I say, two cities within two or three hundred miles, even with a larger discharge of sewage, the natural processes of purification have gone on, the bacterial life period has passed, and the danger is remote.

Q. How about a distance of 20 to 50 or 60 miles?

A. In a river, flowing stream?

Q. Yes, or along the shore of a lake?

A. Well, in my judgment it is an element of the time of travel more than anything else.

Q. As a matter of fact, if you are going to be on the safe side, absolutely on the safe side, it is coming to be believed is it not that the supply of drinking water should be filtered in almost every case?

A. That has been very generally accepted because the physical conditions have absolutely required it.

Mr. Wilkerson: That is all.

Adjourned to Saturday, December 13, 1913, at 10:30 A. M.

Saturday, December 13, 1913, 10:30 A. M.

Met pursuant to adjournment.

Present same as before.

ERNEST W. SCHODER, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?

A. Ernest W. Schoder.

Q. Where do you reside?

A. Ithica, New York.

Q. What is your present occupation?

A. I am a teacher, and engineer.

Q. What is your title?

A. I am in charge of the Cornell University Hydraulic Laboratory, College of Civil Engineering.

Q. How long have you occupied that position, Professor?

A. Nine years.

Q. Will you state your education and training in connection with your work as hydraulic engineer?

A. I was graduated at the University of Washington, Seattle, in 1900 and then pursued post graduate work at Cornell.

Q. For how long?

A. For 2½ years.

Q. Was that in engineering?

A. In experimental hydraulics.

Q. Since that time you have occupied the position which you now occupy?

A. Except for one year in general hydraulic engineering.

Q. What did you do during that year?

A. I was engineer on construction, on two pieces of construction work, a pumping station in Ithaca and a filter plant at Cornell University.

Q. Will you describe the laboratory at Cornell University, the hydraulic laboratory?

A. Our laboratory at Cornell is on a stream having a watershed of some 125 square miles; and we have a pond there of some 20 acres and a canal some 450 feet long, 16 feet wide, from 18 to 10 feet deep; various regulating gates; and a laboratory building which contains many pieces of apparatus on a small scale. Those are the main features.

Q. Are you familiar with the use and operation of the Haskell current meter?

A. Yes, sir.

Q. Did you make any experiments at the request of Mr. Gardner S. Williams, during this year, in the laboratory?

A. I did.

Q. With the Haskell current meter?

A. Yes.

Q. Will you state what experiments you made and the results of such experiments?

A. We made nine discharge measurements in the canal with the Haskell meter, checking the flow by means of weir measurements. These measurements were made at various distances down from the upper end of our lower canal. The

water falls from what we call our upper canal into the lower canal and then passes through a set of baffles, and flows on through the lower canal; so by going various distances down from the upper end of the canal we are in various regions of more or less disturbed flow; that is appearing so to the eye. These measurements were made by what is called the "point" method. That is to say with the water flowing and steady conditions prevailing, we held the meter in various parts of the cross-section of the flowing water, at various distances below the surface and at various distances from the walls of the canal, and observed the number of revolutions in any given time, and from those observations we computed the discharge, using for that purpose a rating made of the meter, checked also during the experiments and after the experiments; and the results of those measurements, summarized, I have here.

Q. Have you any photographs of the canal and the water flowing in the canal, which would indicate the conditions existing there?

A. Yes, we have a number of photographs showing the conditions during the tests.

Q. Were those photographs taken at the time the measurements were made?

A. Yes, I made these in person at the time of the measurements.

Q. Who assisted you in making these experiments?

A. Professor K. B. Turner, and several advanced students who had had previous experience with the current meter.

Q. You had general charge of the work did you, in making the experiments?

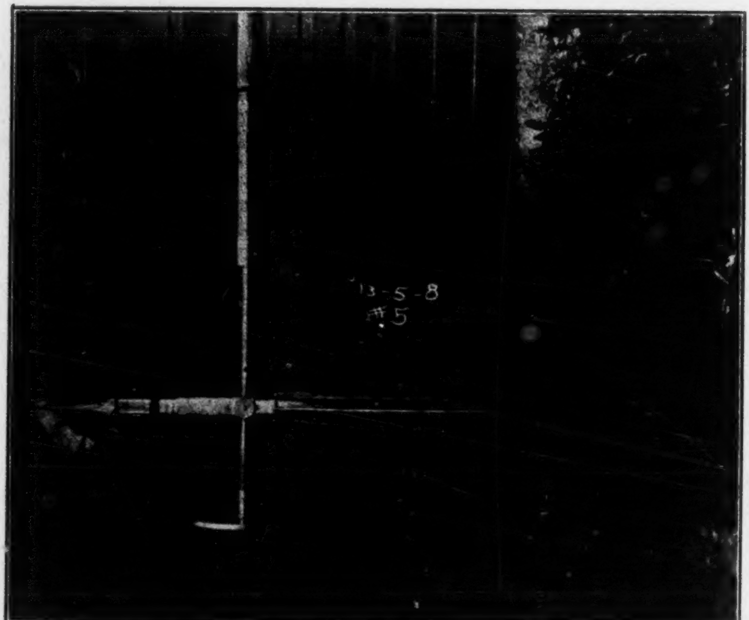
A. General, and also immediate supervision.

Mr. Adcock: I offer in evidence the photograph of the Haskell current meter, to be marked Schoder Exhibit 1, December 13, 1913.

(Photograph so offered in evidence was marked Schoder Exhibit 1, December 13, 1913, and is here inserted.)

SCHODER EXHIBIT 1.

Dec. 13, 1913.

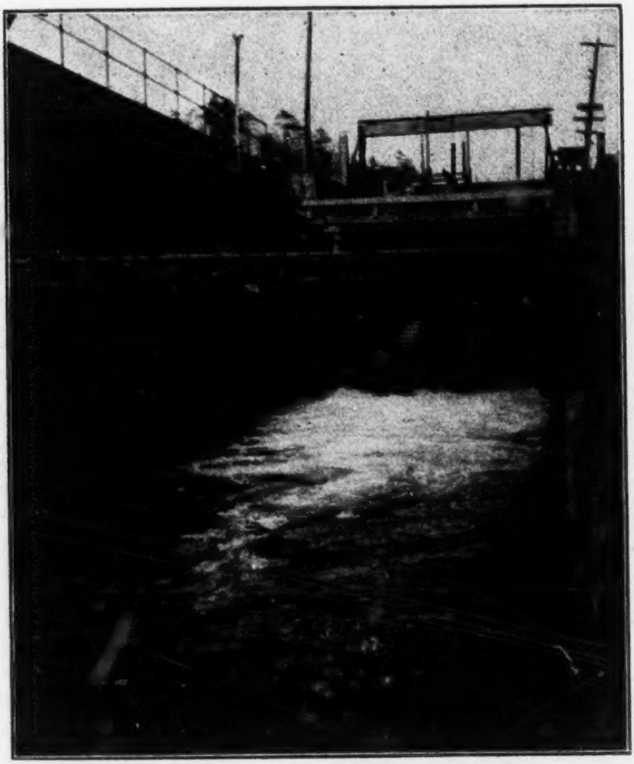


Mr. Adcock: I also offer in evidence eleven other photographs, which appear to show the canal, the water flowing in it, as Mr. Schoder has just described; to be marked Schoder Exhibits 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12, December 13, 1913.

(Photographs so offered in evidence were marked as directed, and here follow):

SCHODER EXHIBIT 2.

Dec. 13, 1913.

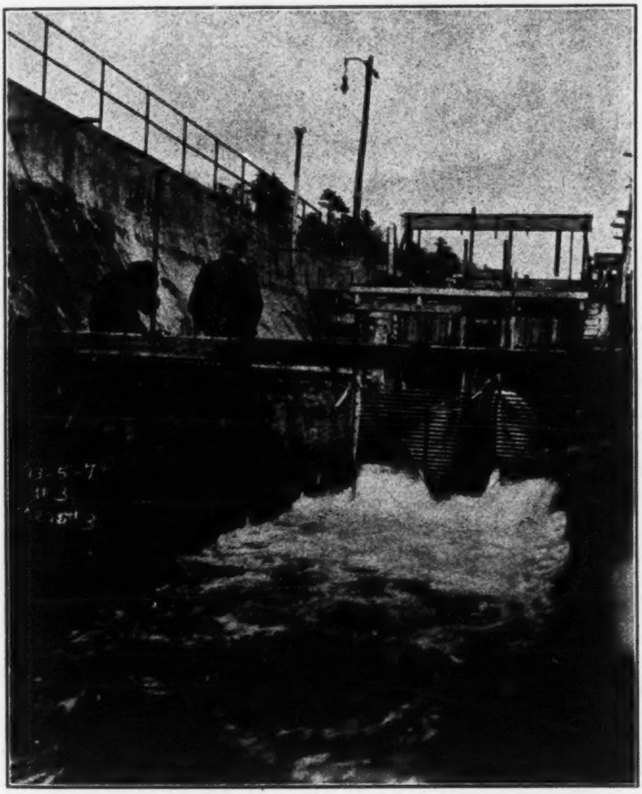


SCHODER EXHIBIT 3.

Dec. 13, 1913.

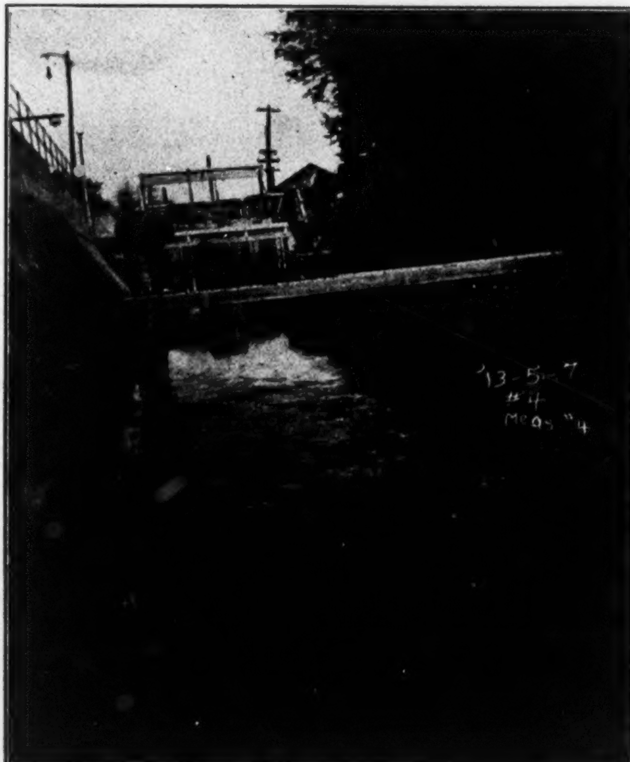
SCHODER EXHIBIT 4.

Dec. 13, 1913.



SCHODER EXHIBIT 5.

Dec. 13, 1913.

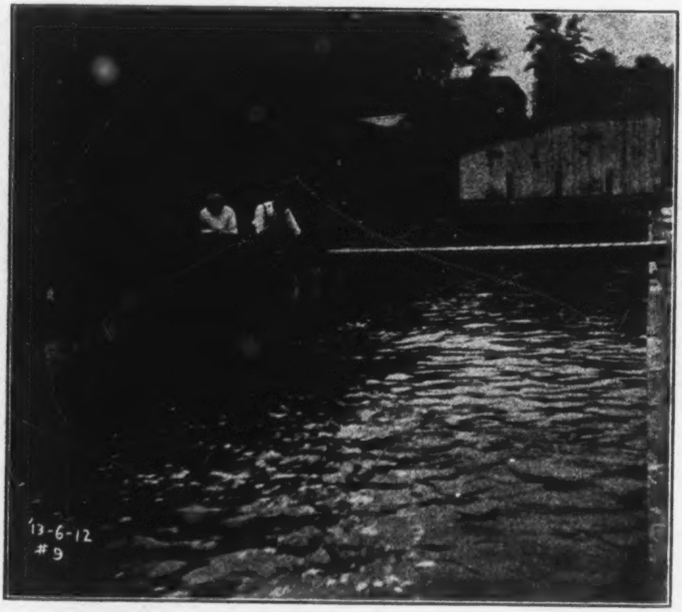


SCHODER EXHIBIT 6.

Dec. 13, 1913.

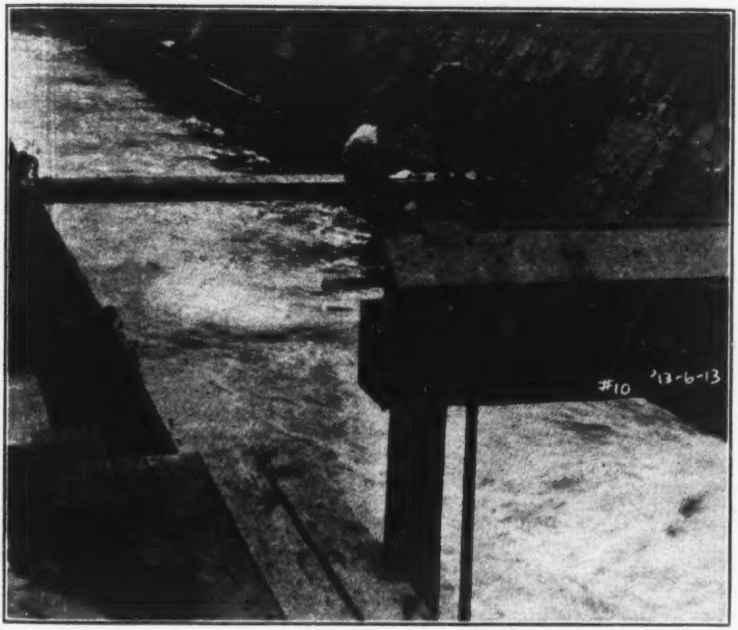
SCHODER EXHIBIT 7.

Dec. 13, 1913.



SCHODER EXHIBIT 8.

Dec. 13, 1913.



SCHODER EXHIBIT 9.

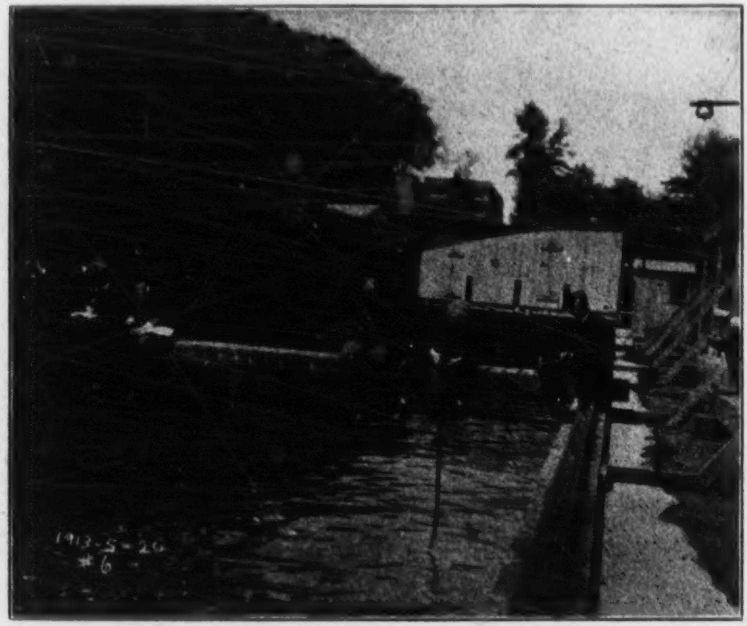
Dec. 13, 1913.

SCHODER EXHIBIT 10.

Dec. 13, 1913.

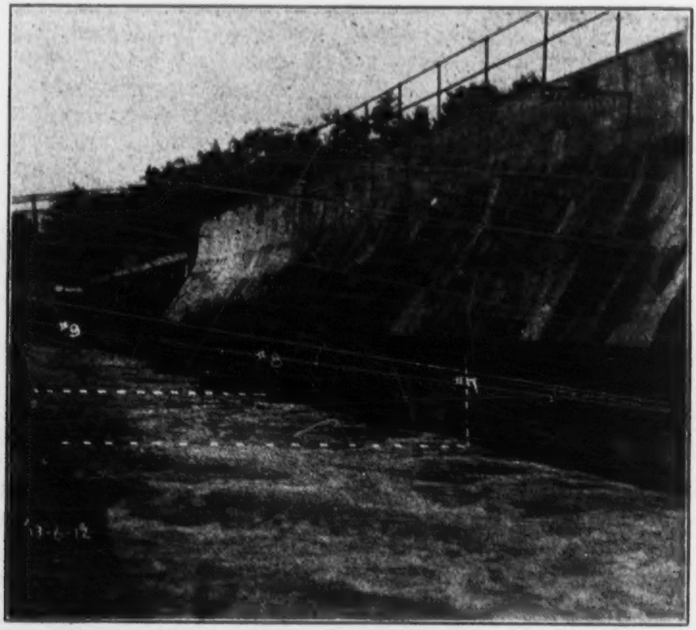
SCHODER EXHIBIT 11.

Dec. 13, 1913.



SCHODER EXHIBIT 12.

Dec. 13, 1913.



Q. Professor Schoder, you have placed some marks and figures in pencil opposite some of these photographs. What do they indicate on these exhibits?

A. They indicate the number of the measurement.

Q. Which you have heretofore described?

A. Yes.

Q. As I understand this water that went through the canal at the time you made these measurements with the Haskell current meter was at the same time measured by means of a weir?

A. Yes, sir.

Q. Will you state now the results of your experiments, continuing your answer to the original question?

A. The sheet I now hand you contains the summarized results of the nine measurements.

(Table referred to by the witness is as follows):

CORNELL UNIVERSITY HYDRAULIC LABORATORY CANAL DISCHARGE MEASUREMENTS BY HASKELL CURRENT METER

No. of Meas.	Distance down stream from Baffles, feet	Mean depth of water in feet	Discharge by meter c. f. s.	Discharge by weir c. f. s.	Deficiency in discharge by meter c. f. s.	%Deficiency of meter meas.
1	51	3.96	159.4	170.6	11.2	6.6
2	260	4.40	161.9	170.6	8.7	5.1
3	51	2.62	164.3	170.6	6.3	3.7
4	88	2.73	161.6	170.6	9.0	5.3
5	208	2.91	165.0	169.6	4.6	2.7
6	41	7.12	166.3	170.5	4.2	2.5
7	67½	7.19	160.3	169.5	9.2	5.4
8	208	7.44	160.4	168.0	7.6	4.5
9	41	7.09	152.3	168.3	16.0	9.5

(Table identified by the witness was marked Schoder Exhibit 13, December 13, 1913, and the original document is inserted here in the transcript of testimony to be submitted to the court.)

Q. Describe what that Exhibit 13 shows?

A. For each of the measurements we have here tabulated the distance down stream from the baffles, in feet.

Q. The first column is the number of the measurement?

A. The number of the measurement.

Q. And the second column is entitled what?

A. The distance down stream from the baffles.

Q. What does that mean?

A. The distance down stream from these boards intended to quiet the flow after falling from the upper weir, and shown in the photographs. That is the distance at which the measurement was made.

Q. Will you refer to the photograph which shows the baffles you speak of?

A. They are shown in this photograph marked Exhibit Number 6.

Q. Also in the photograph marked Exhibit 3?

A. Yes and in Exhibits Number 4 and 5; also Exhibit 10.

Q. Is that the lattice work that we see there?

A. Yes, right there (indicating).

Q. Just above where those men are holding a rod?

A. Yes, it is shown in Exhibits 2 and 3.

Q. What are the baffles for?

A. They were put there in the canal to quiet the disturbed

condition of flow created by the water falling over the upper weir into the lower canal, so that in the lower canal the flow will be much less disturbed than if the baffles were not there. These baffles consist of wooden plank, two by twelve plank, placed one above another with about a two inch space between them from the bottom to the top of the canal, and through those the water must flow, and is guided in a horizontal direction as it flows through.

Q. What does the second column show, entitled "Mean depth of water in feet"?

A. That is the average depth of the water at the point where the meter measurement was made.

Q. That is at 51 feet below the baffles?

A. Yes.

Q. The next column, what does that show?

A. The next column is the discharge by the meter in cubic feet per second.

Q. In that case it is 159.4, is that correct?

A. In number 1.

Q. Number 1 measurement?

A. That is gotten by computations from the point measurements with the meter.

The next column gives the discharge by the weir in cubic feet per second. The next column, the deficiency in discharge by the meter in cubic feet per second.

Q. That is the amount that the meter measurements shows less than what the weir measurements show, is that correct?

A. Yes. The last column shows the percentage deficiency of the meter measurement.

Q. Do you know whether this Haskell meter which you used there is the same type of meter as was used by the United States Lake Survey, in their work?

A. It is.

Q. What does the next column show?

A. That is all.

Q. Did you state what the last column showed?

A. The last column shows the variations in percentage deficiency of the meter measurement from the weir measurement, varying from 2.5 per cent. to 9.5 per cent.

Q. That is in all the nine measurements?

A. Yes. They are all deficiencies.

Q. Those nine measurements were all the measurements which you and Mr. Turner made, were they, at the request of Mr. Williams?

A. Yes.

Q. Do the deficiencies show any apparent law of variation, according to the distance from the baffle or weir?

A. No regular law is apparent, as far as I can see.

Q. Do you know what the velocity of the water was flowing through the canal, at the time you made the measurements?

A. It varied from about 2 to 5 feet per second. I haven't the exact figures in my mind, although they are on the measurement sheets here.

Mr. Adcock: Mr. Schoder has here a number of sheets on which he has made computations. So as not to encumber the record, we will give these to you for the purpose of whatever use you may want them for. It will not be necessary then to put them in evidence.

Q. How long has this weir been used there, Professor Schoder?

A. The measuring weirs have been at the laboratory for 14 or 15 years now.

Q. In your opinion, with what degree of accuracy was the water measured by you as it passed over the weir?

A. Within one per cent. of the truth.

Mr. Adcock: That is all.

Cross-Examination by Mr. Hopkins.

Q. What was the amount of the fall from the reservoir into this canal?

A. About eight feet I should say.

Q. And within what distance did that total eight feet occur?

A. Why right in one place, a single fall.

Q. A sharp drop?

A. Yes.

Q. And how far below the fall are these baffles located?

A. Between 20 and 30 feet I should estimate. I don't recall the exact distance.

Q. Do you know of any meter that is more accurate than the Haskell meter in measuring streams?

A. As a general answer to a general question, yes.

Q. Small or large streams? Go ahead, explain what you mean.

A. I don't understand your question.

Q. Well then confine it to velocities from one to six feet per second, and large streams from 50,000 cubic feet to 250,-000 cubic feet per second, do you know of any meter that is more accurate?

A. No, I do not.

Q. Did you ever make any measurements of large streams?

A. Yes.

Q. What one?

A. The Susquehanna River.

Q. What was the flow per second?

A. About 8,000 cubic feet a second.

Q. What did you use there?

A. The Haskell meter and the Price meter.

Q. Did you rely upon the results obtained, as being fairly accurate?

A. With the emphasis on "fairly," yes.

Q. For what purpose was that measurement made?

A. For the usual purpose of obtaining the discharge, where there was no other means of measurement available.

Q. By whom were you employed to do this, if anyone, or was it simply an experiment?

A. It was an experiment.

Q. For your own enlightenment?

A. Yes.

Q. You say the measurements were fairly accurate, with the emphasis on the "fairly." You mean by that that they were not accurate?

A. I mean that they were accurate within 5 to 15 per cent. of the truth.

Q. Where did that 5 to 15 per cent. come?

A. It came in partly in erroneous measurements of depth, partly in performance of the meter difference from the assumed performance, and partly in disturbances in the flow, which could not be observed; partly in direction of the stream when the meter was out of sight; possibly also varying effects of the wind during the measurement; causes of that sort.

Q. Who was with you on this measurement? Were you in charge of it?

A. I was in charge of the measurement. I had a number of different men with me. Professor Turner was with me. Professor Turner and I had general direction of the work.

Q. When was this?

A. There was one measurement a year ago; one two years ago.

Q. And where was that error, on which side do you think, or do you have any way of determining

A. We have no way of determining.

Q. Then how do you know it was in error? Did you make mistakes in the depths, did you find later that you made some mistakes?

A. I think discharge errors are liable to occur in any measurement of a large river.

Q. It is just simply a question of speculation?

A. No.

Q. You don't know that there were any errors in these measurements. Do you know that there were any, or is it simply guess work?

A. I know that no one has ever proved that it is possible to measure a stream more accurately, generally speaking, than I have stated.

Q. That is the accuracy with which you measured the Susquehanna?

A. The limits I have stated.

Q. Within 5 to 15 per cent.?

A. 5 to 15 per cent. It is no proof of the precision of a meter because a meter records in succession the same flow, when the same methods of observation and computation are used.

Q. Those mistakes of 5 to 15 per cent. may be on one side or the other, may they not?

A. Generally speaking, yes. In particular cases one might be able to say whether—

Q. You may find a consistent error, you mean?

Mr. Adcock: Wait until he finishes.

The Witness: In particular cases the errors might be one way and one would have reason to say on which side they would be.

Mr. Hopkins: Q. What would you say as to your measurements on the Susquehanna River, whether they were above or below?

A. On account of the character of the river there, it would be indeterminate in my judgment whether they would be above or below. The bottom was rough.

Q. Are you acquainted with the A meter, the Haskell A meter, and the B meter?

A. Not by those designations.

Q. Do you happen to know just what size the meter was that you used in these experiments at Cornell?

A. The meter was very closely of the size of a meter which I saw in operation about three years ago by Lake Survey men.

Q. Do you happen to know what size it is?

A. I can't say to which of the categories you refer to it belongs.

Q. In inches, and diameter of the wheel.

A. I should say about six inches in diameter; possibly as great as seven.

Q. You think then Mr. Turner was in error when he says about four inches in diameter?

A. I think that this meter that we used in these tests was larger than that, yes.

I may explain that we have a number of smaller Haskell meters in the Laboratory, the size being approximately as stated by Professor Turner; and we have used those quite a bit since these tests were made. This one I am quite certain is larger than that.

Q. In this possible 15 per cent. of error that you think is inherent in measuring streams, what part of that would you say is due to error in measuring the depth of your streams?

A. One cannot give a general answer to a question of that sort, because conditions are so different in different rivers. In some streams, one might make errors of as much as that, as much as the 5 to 15 per cent. in the depth measurement alone. A rough bottom, changeable surface, a very swift stream and a deep stream, all those causes would contribute to errors, considerable errors in measurement of depth.

Q. In a very large stream with a great number of soundings, wouldn't the uneveness of the bottom tend to be eliminated?

A. With a great depth and not too fast velocity, yes.

Q. And where the surface is comparatively smooth, like a river usually is that is half a mile to a mile wide?

A. Yes.

Q. There you would not have much trouble with the surface, would you?

A. Not much trouble with the surface ordinarily.

Q. In a big stream of that size, of not more than 5 feet per second velocity, couldn't you measure the depth of that and get the cross section with a great degree of accuracy?

A. You should be able to do so if the bottom were not too rough, and if the character of the bottom were known.

Q. The soundings would help determine that, wouldn't they?

A. Not necessarily, in a deep river.

Q. What per cent. of your error do you think is due to winds?

A. That would be different depending on the slope of the stream, on the velocity of the stream. It would be small in percentage with very swift streams, and larger with very sluggish streams.

Q. How does it affect it, by moving the surface water faster or slower?

A. Yes.

Q. You measure relatively close to the surface, don't you?

A. Well, measurements are usually made as close to the surface as it is deemed advisable to go without introducing effects due to the presence of the meter near some limiting medium.

Q. And isn't the direction taken care of to a high degree of accuracy by this tail or vane in these meters?

A. Yes, ordinarily.

Q. What percentage of your 15 per cent. would you charge up to the direction?

A. That would be indeterminate in the case of a stream with a rough bottom, as well as at such depths where the meter could not be seen. Ordinarily, the river flowing regularly and away from the influence of the bottom or the sides, or obstructions in the stream of any character, the error would probably be within one or two per cent. in most cases.

Q. You heard me asking Mr. Turner about shallow streams?

A. Yes.

Q. And the indeterminate area that we were speaking of that you could not measure with one of these meters?

A. I did.

Q. You would also agree that if there is a constant error in your computation of this indeterminate area, it would show much more pronounced in the shallow stream than it would in the deep stream?

A. With the same conditions of bottom and sides, yes.

Q. And other things being equal, the measurements of a large stream are likely to be more accurate than a small stream, aren't they?

A. If in the "other things" you mean the condition of the sides and bottom, yes; otherwise, no.

Q. The only difference being in the size of the stream?

A. If the differences were only in the size of the stream, one should be able to measure a large stream more accurately than a small stream, not however with the same number of point measurements.

Q. You think there should be more measurements in the large stream than the small?

A. Yes.

Q. How much time did you put on these measurements in the Susquehanna River?

A. Each measurement occupied three hours, three to four hours.

Q. You mean each cross section?

A. Yes.

Q. How many cross sections did you measure?

A. Each discharge measurement. You mean at how many different places in the river?

Q. Yes?

A. One. I may modify that by saying really at two. We made these observations at a bridge, and some of the observations were made between the piers, and upstream; and others were made between the piers further down stream.

Q. Did your results at those two places check?

A. Within the limits I have mentioned, they did. I have not the exact figures with me.

Mr. Adcock: That is 5 to 15 per cent.

A. That is from 5 to 15 per cent.

Mr. Hopkins: Q. And if they had checked say within two or three per cent., you would think it would be more accurate, wouldn't you?

A. I would think it was an accident.

Q. Suppose you did that several times, and at several different places in the river, and still would get that check, would you still think it was by accident?

A. What do you mean by that?

Q. That every time they check within a degree of precision, is it always an accident?

A. No, I would not think so always, if they always did that. In my experience, no one has ever found by measuring in different places on the same river with different conditions prevailing, that checks have been closer than those limits.

Q. Are you familiar with all the measurements of the Lake Survey?

A. Not all of them, no.

Q. What is the total time you put on the measurements of the Susquehanna?

A. As I say, each cross section occupied about three hours.

Q. How many times did you measure a cross section?

A. I think four times.

Q. About a total of 16 hours?

A. Something of that sort.

Q. Covering about how long, one or two days?

A. Yes, covering two days, with certain preliminary measurements; possibly four days altogether.

Q. When Mr. Williams asked you to make these tests, did he tell you what purpose they were for, and what condition of perturbation there should be and things of that kind that he wanted?

A. No, he merely gave a general description of the tests wanted, with reference to our laboratory conditions.

Q. What was that general description? What was it that he wanted?

A. That he wished to have the matter tested by measuring as nearly as possible, in various degrees of disturbance, the discharge of a flow which was measured also by a weir, measuring exactly the same flow with different degrees of disturbance, as judged by the eye and as judged by distance below whatever was creating the disturbance.

Q. Did you make any then at a steady velocity, uniform velocity, I believe we spoke of? Did you make any in response to this request of Mr. Williams?

A. Yes, these tests that have been mentioned, these nine measurements were made in response to that request.

Q. Yes, but these are all, judging from the photographs, at quite a degree of perturbation, aren't they?

A. Those further than 100 feet below the baffles were in a region of flow which would be called in any river that I have ever seen just the opposite of disturbed,—rather a steady tranquil flow.

Q. Then your conclusion is that this meter that you used in these experiments under registered under practically all conditions?

A. Under all the conditions of these experiments, it certainly did under register.

Q. Do you think there was any other source of error than the current meter?

A. Only the errors mentioned with the limits of the weir and the method of computation.

Q. Does that method of computation cover this area that you have spoken of as an indeterminate area?

A. It does, with the provision that whatever error was made in computing the discharge tended to overestimate the discharge.

Mr. Adcock: That is the current meter discharge?

A. Discharge by current meter.

Mr. Hopkins: Q. At the time you made the measurements, did you think you were making a mistake all the time and giving a higher volume of discharge than you ought to have given?

Mr. Adcock: That is for the current meter discharge.

Mr. Hopkins: Yes.

A. We knew we were.

Q. Then you knew that you were not making an accurate test?

A. Under the conditions just stated, we knew that there was an error of the nature described, an over estimation. We did not try to eliminate that over estimation by bringing other measuring instruments than the current meter into the question. Had we done so, we could have made a more accurate measurement, by bringing other measuring instruments, such as other meters, other current meters of the Pitot Tube into it. We know about what reduction to expect in cases of this kind, and if we were in doubt we could find out by the actual measurement itself, but this was to be a measurement by current meter.

Q. The sides of your canal are rough, and the bottom smooth?

A. In general that describes the condition of affairs. The sides are rougher than the bottom.

Q. Now is there any uniformity about your results, as to whether your degree of error, or whether the degree of error in the current meter measurements from the weir measurements is based upon the degree of perturbation?

A. As judged by the eye, there appears to be none. That is according to the perturbation as judged by the eye there appears to be none, no regularity or law.

Q. Then there is some other thing that causes this error besides the perturbation?

A. I am not prepared to say that. There are perturbations that may have an effect on a current meter that would

not be apparent to the eye; and there is much reason to think that that is the case.

Q. Why is it that there is such a difference between "one" and "nine," both of which are fairly close to the baffles?

A. I don't know, except that "nine" was made with an attempt to get the discharge by meter with the greatest possible accuracy, or with much greater accuracy rather than "one."

Q. Wherein was there an attempt to get greater accuracy in "nine" than "one"?

A. By making measurements at more points.

Q. But the condition of the water there was practically a rapids, a state of rapids, wasn't it, 41 feet from the baffles?

A. Yes, "one" was 51 feet and "nine" was 41 feet. The conditions of depth were different there. Number 9 was made with water over seven feet deep and number 1 with water about four feet deep.

Q. How do you explain the difference in number six and number nine, both made at the same station, 41 feet below the baffles, number 6 giving the error only 2½ per cent. and the other, number 9, 9.5 per cent.?

A. I think one reason is that number 6 was a measurement made taking fewer points of observation, and that on that account an error came in in estimating the discharge, having at hand only the data from the points where we observed.

Q. If this whole discrepancy were due to the under rating of the Haskell Meter, that difference should not appear should it at the same place?

A. The greater number of points taken in measurement number 9 introduces a somewhat different condition of affairs in the two measurements. One measurement from the current meter standpoint is more precise than the other because we cover with greater minuteness the cross-section. Nine was intended to be an exact duplicate of "six" as far as conditions of flow was concerned, and as far as weir measurements could show it was an exact duplicate.

Q. How about number 8 as compared with number 9 as to the number of observations made?

A. Number 9 had approximately double the number of observations that number 8 had.

Q. Is that true of "nine" with relation to all the other eight?

A. It is.

Q. Then there seems to be quite a difference in your result, when you had a greater number of observations?

A. The only index that we have of that is the comparison of number six and number nine. Comparing the other observations, comparing numbers 1 to number 8 inclusive, where the number was about the same, or where the spacing was about the same, the discrepancy in those appears to give a wide variation, without including number 9 at all.

Q. But not so wide as the difference under the same conditions when the number of observations was the only difference?

A. No, because number 6 and number 9 were the only two taken as close to the baffles as 41 feet.

Q. Then wouldn't it have been fairer to have given a list where the observations, number of observations were taken in the same way, all nine like "nine," as the eight without "nine"?

A. We made more measurements. We desired to find out exactly what would happen under these conditions and we made more measurements than I think anyone has ever made before. Our time was limited, and we did the best we could. The results are here.

Q. The point is this: You show a great discrepancy at some place when you double your number of observations. If you had doubled the number of observations all down the line, your results at some of the better places, say where it was over 100 feet below, might have been entirely different from what you have given there?

A. They probably would have been more precise.

Q. And might have registered more than you have there?

A. Might have registered more or might have registered less, yes, sir.

Q. So that in what you call the greater degree of precision, we do not have the measurements all the way down. We only have them at this turbulent place right under the rapids?

A. We do not have an ideal degree of precision anywhere. Measurement number 9 was made to be an exact duplicate of number six, to see what result would be gotten by taking a greater number of measurements, but especially because when the results of number six were carefully scrutinized, it was seen that there was a rapid change of velocity from point to point, and to eliminate the uncertainty coming from that we made measurement number 9. That appeared, I think, in greater degree for number six than any other measurement from number one up to number eight. Referring to number three, 51 feet below the baffles, it appears from this sheet

that you gave me that on one side, half a foot from the side, the velocity is 2.47 feet per second; on the other side, a half a foot from the side, the velocity is 4.05, which indicates there is a very strong cross-current, doesn't it?

A. Indicates that the velocity is higher on one side than the other; indicates of itself nothing as to cross-current.

Q. You are 51 feet from the baffles at that place?

A. Yes, sir.

Q. Is it likely that the water would flow that entire 51 feet with so much difference in velocity on the sides?

A. 51 feet is relatively a short distance in a canal as large as that. It is only three times the width of the stream.

Q. How do you explain how it happened that that is the case?

A. I think the conditions of flow are such that the water can flow a little bit easier on one side than the other; and there would be a great many different conditions that would have to be analyzed to show just why the water flows faster there than elsewhere.

Q. Would you expect that condition to keep up, one side faster than the other, for 30 feet more?

A. I should think that the further down stream you get in a regular canal the more nearly the water would assume a uniform condition of affairs.

Q. How far down would you expect it to get uniform?

A. I think every added width of the canal down would have some effect; and when one went ten times the width of the canal down stream, the condition of flow should become more settled.

Q. Take number 5: On one side you have got a velocity of 2.95; on the other side you have 3.39.

A. Your statement of 3.39 refers to the 13 foot point. You should look at the 2.95 as against 2.81.

Q. In measurement number 4, 88 feet down, they are just the same?

A. 3.12 and 3.12.

Q. Did you make any measurement of the direction of flow in each particular section?

A. We observed very carefully for direction, and found in practically every case the direction of flow was either straight down the canal, or so close that no correction was necessary on account of direction.

Re-direct Examination by Mr. Adcock.

Q. How rough were those sides? Were they rough enough to cause any particular disturbance in the flow of the water?

A. They were rough in comparison with the bottom rather than rough as we speak about a river bottom being rough. The bottom of the canal is what would ordinarily be called smooth cement finish. The sides are rougher due to a disintegration of the surface finish; and show the gravel in places sticking through, and sticking out a little, so that from place to place there are variations in the degree of roughness. Here it would be sand in appearance, and here with some gravel sticking out, but the general degree of roughness is not such as to cause any high degree of disturbance of the water. The flow of the water proceeds through without any high degree of disturbance.

Q. This disintegration has been going on for some time has it not?

A. Yes.

Q. Now these baffles that are used there, how long have they been used in that canal?

A. Baffles of this same sort?

Q. Or a similar description?

A. Baffles of this same sort have been used ever since I have been there, and judging from photographs earlier and descriptions of tests, they have been there since the first experiments made on the canal.

Q. And the purpose of baffles, as I understand it, is to smooth out the disturbed conditions resulting from the fall of the water over this upper weir, isn't it?

A. Yes, sir.

Q. And to produce a condition of flow similar to that which would obtain, or does obtain in streams or rivers.

A. Yes sir, produce a condition of normal flow.

Q. And this is the same canal that Professor Turner spoke about, that is maintained by the Cornell University, and over which Professor Haskell has charge, is that correct?

A. Yes, sir.

Q. Do you recall whether the United States Government has made any tests of measuring devices there, such as current meters, in that canal?

A. There have been a number of measurements made by the United States Government, various departments, bureaus

of the same, with various measuring devices, current meters, weirs, dams.

Q. Did they re-calibrate the weir when they made their measurements, do you know?

Mr. Hopkins: That is objected to as immaterial in this case?

A. The standard formulae for weir flow over weirs of this description have been used by all the Government Departments or Bureaus that have made tests there. I may say that those departments include the United States Geological Survey, the Irrigation Investigations Branch, Department of Agriculture, the Deep Waterways Commission.

Q. The International Waterways Commission, do you know whether they made any measurement?

A. In fact I was thinking of that commission; the International Waterways has also been there. I was thinking of the International Waterways Commission, when I made that statement.

Q. The Board of Engineers on Deep Waterways; that is the same thing as the Deep Waterways?

A. That is the Deep Waterways.

Q. Do you know whether the International Waterways Commission made any tests of the models of a weir which they proposed to use in connection with regulating works in the Niagara River, in that canal?

A. Yes, sir, they did. I acted in an advisory and supervisory capacity for those tests.

Q. As I understand it, Professor, your opinion is that in a number of observations in a large stream by the current meter, the error might be all one way, in each measurement?

A. Yes, sir.

Re-cross Examination by Mr. Hopkins.

Q. They might be anyway might they not, Mr. Schoder?

A. Generally speaking, yes; specifically speaking, there would be many reasons to indicate which way. It would depend entirely on the case in hand, the river in hand.

Q. But it may be, assuming your conditions, either above or below?

A. It would be above in some cases and below in others.

Further Re-direct Examination by Mr. Adcock.

Q. Or it might be all one way, depending on conditions?

A. Under certain conditions, the error undoubtedly would all be one way.

Q. Do I understand you to say that the personally equation might enter into the making of measurements of this kind, such as the determination of the depth of the river and the cross-section and so forth, and the placing of the meters and the determination of verticals, and so on, by the person who makes the measurements?

A. Oh, yes, most emphatically; judgment enters in, very largely.

Mr. Adcock: That is all.

KENNETH B. TURNER, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your full name?

A. Kenneth B. Turner.

Q. Where do you reside?

A. Ithaca.

Q. What is your present occupation?

A. I am a teacher and investigator.

Q. In Cornell University?

A. Yes.

Q. How long have you been in that position?

A. About seven years.

Q. Previously what did you do?

A. I was a student at Cornell for five years taking the degrees of C. E. and M. C. E.

Q. What are those degrees?

A. Civil Engineer, and Master of Civil Engineering; and I was with the United States Lake Survey for about 20 months.

Q. When was that?

A. That was the beginning of 1905, January, 1905, to September, 1906.

Q. Was that before you took your position?

A. That was after my training at Cornell.

Q. That was between the time that you—

A. Between the time I finished my education there and when I started teaching.

Q. What work were you connected with while you were with the United States Lake Survey?

A. The first work with which I had anything to do was in connection with some river discharge measurements at Sault Ste. Marie, Michigan, discharge measurements of the St. Mary's River.

Q. Where were those discharge measurements made?

A. They were made at Sault Ste. Marie, about a mile below the rapids at that point.

Q. How many measurements were made there?

A. I can't state exactly, about between 50 and 60.

Q. That was in what year?

A. That was February and March, 1905.

Q. With whom were you connected?

A. Mr. Murray Blanchard.

Q. In making those measurements?

A. Yes.

Q. Who was the Principal Civilian Assistant?

A. Mr. E. E. Haskell at that time.

Q. That is Professor Haskell of Cornell University?

A. Yes.

Q. He is the inventor of the Haskell Meter?

A. Well, he is a co-inventor, I believe. I believe the Ritchie people have interests in common with his.

Q. Were you engaged in any other meter measurements during that time?

A. No, I was not.

Q. What did you do during the rest of the time that you were with the United States Lake Survey?

A. The rest of the time I was occupied reducing these observations, that is making the computations, immediately following the discharge measurements, and after that I was traveling around the lakes collecting data with reference to evaporation, temperature records and so on.

Q. How did you make those measurements?

A. The measurements were made under the ice. Of course the river was frozen over at that time. We laid out a section across the river.

Q. Was the Haskell Current Meter used in that connection?

A. It was.

Q. What other training have you had besides what you have mentioned?

A. While I was a student at Cornell, I was in the New York State Department, for about three months, in connection with road construction. And since being at Cornell, I have been employed along the lines of hydraulic experimentation, having participated in a number of commercial tests there, and in conjunction with Professor Schoder, have carried on some investigations of our own along the line of hydraulic experimentation.

Q. During that time did you have any occasion to use a current meter, Haskell meter?

A. Used the current meter very much. We have used the Haskell meter considerably in connection with class work; also in connection with investigation work on the canal.

Q. You have made various experiments?

A. Yes, we have used it at frequent intervals, during the time I have been there.

Q. Did you, with Professor Schoder, carry on any experiments, make any experiments at the request of Mr. Gardner S. Williams at the laboratory during this year?

A. We did.

Q. When were they made?

A. During the months of May and June of this year.

Q. Will you state what connection you had with those experiments, in the making of them?

A. I was associated with him in the experiments, taking part in the observations and the reduction of data. I participated however, in only five of those nine measurements. In the last four measurements, I was not a participant.

Q. What can you say as to the accuracy with which these current meter measurements were made by Professor Schoder, as compared with the work of the United States Lake Survey that you were on?

A. They certainly were as accurate, and relatively I should say there was greater accuracy in that the conditions we had to work under were more fixed and our observations were of a nature where we could fix them more definitely, to the best of my knowledge.

Q. Did you have anything to do with determining the volume of water, as shown by the weir?

A. I did.

Q. With what degree of accuracy do you consider the weir measurements were made?

A. We considered that the weir that we used is accurate well within one per cent.

Q. Will you describe the experiments which you made at the St. Mary's River, and the results?

A. I will have to rely in part on memory of course, because it has been some time.

Q. If you have any data here that you wish to refer to you can do so.

A. Do you wish me to state the method of observation and the results?

Q. Yes.

A. As I stated, our section was laid out across the river, we having the meter stations at intervals of 100 feet; the stations being holes cut through the ice at that distance apart. And in connection with the discharge measurements we observed velocity distribution in the vertical; that is the variation of velocity in the stream from the surface to the bottom, in these different stations; and during the series, (the entire series of discharge measurements), we observed in those stations a varying number of vertical velocity curves, varying from about 10 to 12 in some stations to about 17 in others.

In those verticals, the method of observation was to take a surface observation. That invariably was taken one foot below the ice. Then we took a bottom observation, which was at a distance above the bottom equal to the distance of the meter axis from the standard or weight which is used. Then the intermediate distance was divided into ten parts and the meter suspended in turn at each of these tenths, using what is known as the proportional method of observations in the vertical, so that that series of observations would give eleven determinations for each observation of the vertical. And all the verticals taken during the season at any one station were summarized, the average result taken, and the relation found between the mean velocity as indicated by that average and the velocity at 5/10ths depth.

The reason for getting this relation between the mean velocity and the 5/10ths was that in the discharge observations themselves, the meter was lowered directly to the 5/10ths depth point, and an observation made at that position. Then the figures on that observation are used in connection with computing the discharge, by taking the result of such observation and modifying it by the index coefficient which was obtained from the average vertical curve, as before stated. So that a discharge measurement consisted in measuring in turn from station to station across the stream the velocity at the 5/10ths point, measurement at each station point being made.

Q. Do you know how the method which you have described compares with the method usually used by the United States Lake Survey in making such measurements?

A. Those measurements are the only ones I have participated in directly, and I can't say as to other measurements absolutely. Those measurements were along the same line as those made back in 1896, at about that same point in the same stream.

Q. Were they made under the direction of Professor Haskell?

A. Under the immediate direction of Mr. Blanchard, who was in charge of the field measurement.

The general scheme was the regular lake survey scheme.

Q. What was the condition of flow there as to velocity or disturbance of the water?

A. The section was laid out at this point primarily to involve all the flow passing down the stream. That meant that we had to lay out our section below the tail race of the Michigan Power Company, and efflux from the power company there, coming into the stream at about right angles to the normal flow of the river gave us an eddy on the American side of our section. That is, apparently the water was flowing upstream at that point for a distance of about six or seven hundred feet from the American shore.

The velocity in the whole section was relatively low. The mean velocity of the whole river, as I recall was low. I am not exactly clear about the observations in a number of places. The maximum was under two feet a second; I should say about 1.8.

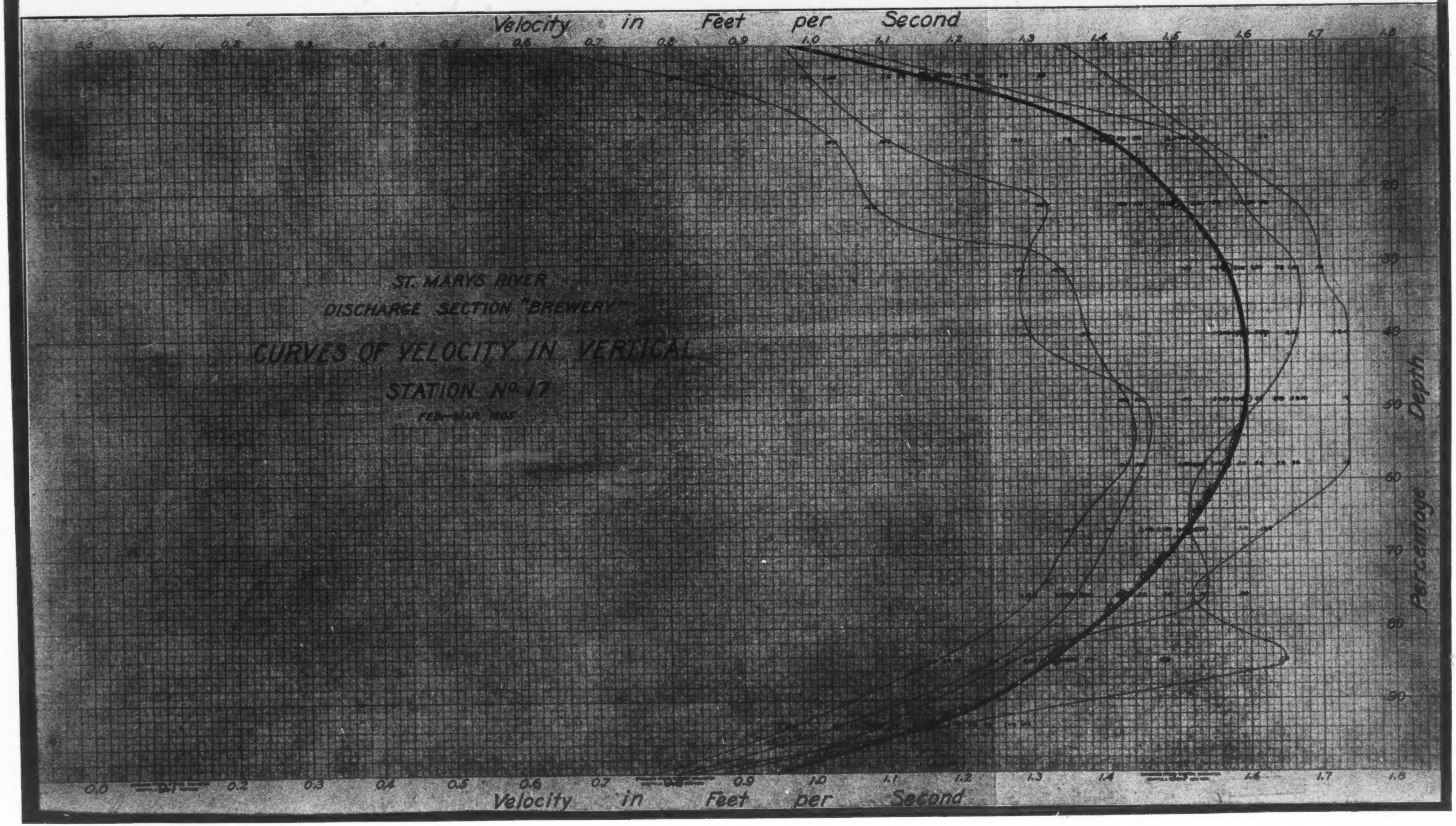
Q. Have you any plottings here of the vertical curves?

A. I have a plotting of the vertical curve observations in one of those places called station number 17, which means 1,700 feet from the American shore, about in the middle of the river.

(Producing plat.)

Mr. Adcock: I offer this paper that Professor Turner has referred to in evidence, and ask that it be marked Turner Exhibit 1 of this date.

(Plotting referred to by the witness, was marked Turner Exhibit 1, December 13, 1913, and here follows):


Velocity in Feet per Second
ST. MARYS RIVER
DISCHARGE SECTION "BREWERY"
CURVES OF VELOCITY IN VERTICAL
STATION No 17
FEB-MAR 1905
Percentage Depth
Velocity in Feet per Second

Q. Will you describe Turner Exhibit 1, which you have referred to, and state what it shows; how it was made and so forth?

A. This exhibit was made on the train last night, I will say by way of explaining the character of the plottings and so on. What is intended to be portrayed is the individual vertical curves and depths of one particular station.

Q. What station was that?

A. Station number 17. This plotting shows how the velocity in the vertical at that station varied between measurements, or from measurement to measurement.

Q. Explain this, so the court will understand giving for instance the top of the curve to the left, how did you get that?

A. The curve begins usually at the top, what we call the surface point. The observation at that point, as above stated, was one foot under the ice and the bottom observation on the curve was made at a point 1-1/2 feet above the river bottom. The intermediate points were made at tenths of depths from the surface to the bottom. That is instead of going down foot by foot, or any even measured distance, the meter was lowered by proportional depths; lowered one-tenth of the whole depth for each position.

Q. What is the heavy red line?

A. The heavy red line in this plotting is the average of these fourteen different curves.

Q. Is that solid line the average, as computed by the lake survey?

A. It is.

Q. Now you have four dotted lines there, irregular dotted lines. What are they?

A. Those dotted lines indicate four of these fourteen verticals before mentioned, which have been traced in in ink. The other ten are not traced, although the points are plotted.

Q. They could be traced?

A. They could be traced.

Q. Do they show substantially the same variation as the four which you have there?

A. These four show rather the extreme.

Q. That is the outside of one, the outside of the other; the extreme?

A. Yes, these four were traced in to show the range.

Q. What do the figures .3, 1.8, mean?

A. Those are the velocities in feet per second.

Q. And down the right hand column, what do those figures indicate?

A. Those are meter positions expressed in percentages of the total depth.

Q. Now if you desire to get the average velocity at any one point, at any particular depth, how would you do it?

A. I don't understand the question.

Q. Professor, what would be the average velocity from all the observations, made at .3 depth, say?

A. The average velocity at .3 depth, taking into account all the observations made at that point, would be the numerical average of all the observations made at that point; and it is shown on this plotting by the full line, the value which the full line indicates at that point.

Q. What is that?

A. That, on this particular plotting, is 1.585 feet per second.

Q. What is the actual velocity shown at .3 depth as shown in curve numbered 14; that is the dotted line?

A. Curve number 14 which refers to the 14th observation for velocity in the vertical shows a velocity at .3 depth of 1.290 feet per second.

Q. What is the velocity at .3 depth of curve number 1, as shown on that exhibit, the dotted line?

A. The velocity shown by curve number 1 at .3 depth, is 1.705.

Q. What is the velocity shown on the mean curve, that is the heavy line, at .5 depth?

A. The velocity shown at .5 depth by the mean curve is 1.610 feet per second.

Q. And by curve number 14 at the same depth, the dotted line?

A. And the velocity at same depth, .5, as shown by curve number 14 is 1.455 feet per second.

Q. And also the same question as to curve number 1, the outside dotted line, the one furthest to the right, same depth?

A. The corresponding velocity as shown by curve number 1 is 1.740 feet per second.

Q. What is the percentage variation in velocity from .3 depth to .5 depth shown on the average curve, the mean curve?

A. Referred to which point?

Q. Refer it to the .5 depth?

A. The percentage difference in velocity between the

velocity at .5 point and that at the .3 point, as shown by the mean curve, using the .5 point as reference, is 1.55 per cent.

Q. Referring to curve number 14, what is the same relation, the variation?

A. The percentage variation in velocity between that at the .3 point and that at the .5 point, as shown by curve number 14, using .5 point as reference, is 11.34 per cent.

Q. Referring now to the curve number 1, what is the variation?

A. The percentage variation between the velocity of .3 depth and that of .5 depth, as shown by curve number 1, using .5 depth as a reference, is 2.01 per cent.

Q. Now will you make the same calculations as to the same curve at .9 and .8 depth?

A. The percentage variation between the velocity at .8 depth and that at .9 depth, as shown by the mean curve, using the .8 point as reference, is 6.30.

Q. Give the same percentage as to each curve that you mentioned?

A. The percentage variation between the velocity at .8 depth and that at .9 depth, as shown by curve number 1, using the .8 point as reference, is minus 7.15 per cent.

Q. What does the minus sign mean?

A. The minus sign means that the velocity at the .9 depth point is greater than that at the .8 depth point, which is contrary to what is shown by the mean curve for those positions.

Q. Make the same comparison as to curve 14?

A. The percentage variation between the velocity at the .8 depth and that the .9 depth, as shown by curve number 14, using the .8 depth as reference, is 8.32 per cent.

Mr. Hopkins: Q. Why were these four curves you have here selected, namely 1, 13, 14, and 6?

A. The idea of course was to trace in all those curves, but time precluded that and only those showing the extreme range of variation were sketched in.

Q. This entire plat was based upon one station?

A. One station.

Q. What station is that?

A. Number 17, meaning 1700 feet from the American shore.

Q. And about what part of the river is that?

A. Very nearly in the center. The river was about 3350 feet wide at that point.

Q. Why was that particular station selected?

A. Because at that station it was well removed from the eddy part of the stream and at a point where the velocity was about the maximum and it was assumed that the conditions there were as good as anywhere. I mean to say that I simply preserved these sheets from my own desire to have something of the kind to show that I had been connected with the work.

Q. You think that where the velocity is high, that makes conditions more favorable to the measurements?

A. It would be much better than in a station near the eddy where the velocity was lower, ordinarily.

Q. When you say that there was a percentage of variation on a certain curve here, comparing your .3 and your .5 depths, will you tell us again just what you mean?

A. I mean that reading the velocities indicated by any particular curve that may be under discussion at these two points shows that the velocity at one point differs from the other on a percentage basis by the amount stated.

Q. In other words at this station 17, a certain velocity is read at .3 depth?

A. Yes.

Q. Then a reading is made at .5 depth?

A. Not immediately following. Those velocities were observed in water beginning at the surface and going down towards the bottom by tenths of depths.

Q. Then you read .4, then .5?

A. Yes, and so on.

Q. You mean the velocity at this .5 depth is different from that at the .3 depth?

A. That is what the curve shows.

Q. And this percentage you were giving is the percentage of difference?

A. Yes.

Q. Taking one as a reference?

A. Taking one as a reference, yes.

Q. These curves that you have platted here, are based upon how many readings at a particular depth, at this station?

A. Usually one.

Q. One, so that this percentage of variation which you have testified to is based upon one reading at .3 depth and one reading at .5 depth?

A. As a rule.

Q. Now how many meters were you using, at the time you made these readings?

A. One meter.

Q. About how long do you permit the meter to remain at one particular depth?

A. One minute, I believe, was the time.

Q. About how long would it be between the time that you measured or took a reading at the .3 depth and the time that you would take a reading at .5 depth, taking into consideration the time that you were noting this down and changing your depths, and all the things that you did?

A. From the time of beginning a reading at the .3 depth to the time of ending one at .5 depth would be something like 4 minutes I should say. The 13 readings were taken as a rule, in about 11 or 12 minutes, covering the whole vertical within that time. I mean the whole vertical was covered in from 11 to 12 minutes, or something like that.

Q. What was your maximum percentage of variation as you gave it here, do you recall?

A. I will have to refer to the record. I do not recall it.

I note one of 11. Possibly there was one greater than that; I cannot recall.

Q. Just what conclusion do you draw from this percentage of variation that you have been putting in from this curve?

A. That the conditions of flow at that point vary from time to time; that the water is surging there, and not only the velocity itself is changing, but the distribution of the velocity in the vertical is changing.

Q. Is there any particular reason that that condition existed at that particular place?

A. That condition exists in all flowing water.

Q. Any special reason for it at that place?

A. Not that I know of in particular.

Q. Isn't there a sand bar above this point?

A. I don't recall.

Q. About the middle of the stream?

A. I can't state about that.

Q. Do you know whether there is one or not?

A. I don't know.

Q. What other stream do you know of where the conditions are changing to that extent between .3 and .5 depth within 4 minutes?

A. No stream of that size that I know of, because I have

not been associated with measurements on any other stream of this size.

Q. How far below the rapids in the St. Mary's River did these measurements take place?

A. I will have to use my recollection of the conditions there.

Q. To the best of your recollection?

A. About a mile I should say, possibly a little more or a little less.

Q. What is the fall in the rapids?

A. That varies, of course, from time to time.

Q. Isn't there about a 20-foot fall there in a short distance?

A. At certain times of the year. Other times it is 18, sometimes less.

Q. How much less?

A. In the case of ice jams in the lower St. Mary's River, at times, it is several feet less than that.

Q. At this particular time, about what would you say was the fall?

A. I can give you the exact figures in a moment; on the average about 17.4 feet.

Q. In what distance was that fall?

A. That is the fall between what is known as gage number 1, which was located at the entrance to the canal above the rapids and gage number 3, which was located at our section.

Q. About three-quarters of a mile?

A. Yes, possibly a mile; more than three-quarters I should say.

Q. What was the total depth of the river at that particular station?

A. At what time? That varied of course with the stage.

Q. At the time this measurement was being made?

A. Which one? There were 14. The average depth? I can give you the average of all of them.

Q. The average depth?

A. 23.1 feet under the ice.

Q. Was there much variation in that?

A. The extreme, covering the range of the curves on that sheet, was about half a foot, between .5 and .6 of a foot.

Q. All this, you say, was under the ice?

A. Under the ice.

Q. At this season of the year, isn't it likely that there was

ice and slush under the surface ice, that might tend to interfere with the flow?

A. Not very likely. During the February measurements, there had been no breaking up whatever of the ice, and the conditions were assumed to be good at that point. We investigated the stations in the immediate vicinity of the holes by reaching under and scraping around, and found no obstructions at the station. We assumed the conditions were good during the discharge measurements, except possibly the last four or five, when the river began to show signs of breaking up.

Q. When there is a slow running stream, the velocity is low as it is here, it is much more likely that there will be at a particular point a change in velocity than when there is a very high velocity in an open river?

A. As a rule, one would look for fixed conditions under normal velocity and a relatively higher velocity as we have here. That is why this station 17 was chosen, because it had the highest velocity of any station in the river.

Q. Which runs from .8 of a foot per second to—

A. About 1.75.

Q. 1.75 feet per second. So that at the highest, that is a relatively low velocity, isn't it?

A. Relatively low, in comparison with other streams; relatively high for the St. Mary's River at that point.

Q. You would not expect as accurate measurements under ice as you would in an open river, would you?

A. I should expect the measurements themselves would be equally accurate in either case. I don't just understand what you mean by the question. You mean the observations themselves?

Q. Any one observation would probably be just as accurate, I understand that is what you mean by your answer?

A. Yes.

Q. But when you are comparing one with the other, aren't the conditions more likely to be changeable under ice than they are in an open river, so that you cannot compare one with another? You would expect this percentage of variation that you speak of to be materially less in a higher velocity, wouldn't you?

A. I would have to know the conditions, of course, under which that higher velocity was obtained, or under which it obtained.

Q. Other conditions being the same?

A. A stream in high velocity tends to keep its regimen a little better than one in low velocity, I should say.

Q. You would suppose that if meters were read simultaneously at the two places that there would be a better check likely, wouldn't you?

A. Two meters you mean at the same point?

Q. Yes?

A. Providing they were not near enough to each other to create any local disturbance.

Q. Where you read them, one at the .3 and one at the .5 point?

A. Yes, I should say that two meters would probably give greater accuracy than one.

Q. Are you acquainted with the method used by the Lake Survey in what is known as the two meter work?

A. No, I don't think I am. I do not recall it.

Q. Then you do not know that on the other rivers all of the coefficient work of the Lake Survey in the measurement of these rivers was done with two meters or more?

A. I know that some of it was not.

Q. Which particultar ones?

A. I recall statements by Mr. Blanchard when he used a battery of 10 or 11 on the St. Clair River.

Q. Two or more was my question?

A. Oh, yes, two or more, I understand.

Q. You say you would expect them to give more accurate results?

A. Judging from the velocity curves there, I would say that one would conclude that way. That is merely a statement of what I believe to be so. I have no data; I have not been associated with conditions of that kind.

Q. Do you think it is a fair comparison to take a low velocity compared to the velocity in the other rivers, the St. Clair, the Detroit and Niagara and take extreme conditions, the curves showing extreme discrepancies, as you have here, and use that as a basis of criticising the measurements on the other streams?

A. I am not criticising the measurements on the other streams.

Q. Again then, what is the conclusion you draw from this, just simply that that particular place and under the conditions that you have described there, there might be a discrepancy such as you have mentioned?

A. These are measurements with which I was directly connected, and are the only data of the kind I have had from actual observation, and these have a bearing on the experiments which we made at Cornell.

Mr. Hopkins: I move that all of the testimony in regard to these measurements on the St. Mary's River be stricken out, because it is shown there is absolutely no connection between them and the conditions at other places, and that the same people made the measurements in any way that they can be used as a basis for criticising or throwing any light upon any of the other measurements involved in this case.

Recess to 2:00 P. M.

After recess 2:00 P. M.

KENNETH B. TURNER resumed the stand and testified further as follows:

Cross-Examination by Mr. Hopkins.

Q. Mr. Turner you say you have been for about six or seven years instructor at Cornell?

A. Instructor for two years, assistant professor for five years.

Q. Who is the head of your department?

A. Professor I. P. Church.

Q. What is Mr. Haskell's position?

A. He is Professor of Experimental Hydraulics and Director of the College.

Q. Just what is your department?

A. My title Assistant Professor of Hydraulics would indicate that I am in the mechanics and hydraulics department of which Professor Church is the head.

Q. And of which Mr. Haskell is the—

A. He has nothing directly to do in that department, except he has general supervision over the whole college. His work does not lie in close connection with that.

Q. What is his title?

A. Director of the College and Professor of experimental hydraulics.

Q. That is E. E. Haskell, is it?

A. E. E. Haskell.

Q. Are you familiar with the St. Clair, the Detroit and the Niagara Rivers?

A. I am familiar with the rivers, in that I have been on them, and up and down them.

Q. Are you familiar with the Niagara River at the International Bridge and above it, the section there?

A. No.

Q. Have you seen the river at the International Bridge?

A. Yes, I have been over the International Bridge.

Q. Have you examined the general surface conditions there?

A. No, I never had any occasion to.

Q. You observed them?

A. Just casually as anybody would, passing over the stream at that point; not having any immediate connection with the conditions there.

Q. The river is rather wide at that point, isn't it?

A. I should say half a mile, maybe more. I do not recall the exact figures.

Q. And flowing straight ahead? There is no obstruction in it that you could observe?

A. Nothing beyond the obstruction that the bridge itself would cause, so far as I know.

Q. About how wide are the spans in that bridge?

A. I haven't any idea.

Q. As compared to that canal at Cornell?

A. I haven't any idea, because I don't know anything about the dimensions of the bridge.

Q. Mr. Haskell is the head of this experimental laboratory isn't he at Cornell?

A. He doesn't do any work in the laboratory and never has. He is Professor of experimental hydraulics, but does not do any immediate work there.

Q. How many meters did you use in these experiments at Cornell?

A. One meter.

Q. What was its size?

A. I can't state exactly. I think it was about four inch diameter wheel, possibly a little larger. It was the harbor meter, so called.

Q. Harbor meter?

A. Harbor meter so called, remodeled for these experiments; that is the direction device was removed and the shaft substituted in place of the direction device.

Q. Did not have this vane on the rear?

A. It did have a tail or direction vane.

Q. How long was that?
A. Just an estimation, I should say between 18 inches and two feet.
Q. Was that the entire meter, or just the vane?
A. The vane or tail part.
Q. It is not what is known as an A or B meter, is it?
A. I can't say. I do not know about that.
Q. Are you acquainted with what is known as the A meter?
A. No.
Q. Or the B meter?
A. No.
Q. As a matter of fact the meter that you were using was entirely designed by Mr. Haskell, wasn't it?
A. I believe it was, to the best of my knowledge.
Q. The only part that Ritchie had anything to do with was some compass, or something of that kind, but nothing of the meter that you were using?
A. I do not have any direct knowledge on that question. I do not really know whether Dean Haskell is involved alone or not; I have no knowledge. It is called the Haskell meter. That is as far as my knowledge goes.
Q. Do you know of any meter in use that gives any more accurate results than this meter?
A. Under certain conditions, yes.
Q. What conditions?
A. Conditions of low velocity primarily.
Q. What would you include within your limits of low velocity?
A. Down below a half a foot a second.
Q. Above a half a foot a second, do you know of any meter that would give any more accurate results than the Haskell meter?
A. No, I don't think there is any that gives more accurate results. I think one is as good as another under those conditions, aside from the standpoint of convenience in use and so on; convenience of recording, and things of that kind that are outside of the meter itself.
Q. Are there any other meters except this cup meter?
A. There is what is known as the Voltman Meter, the old type screw meter, which was really a forerunner to the Haskell Meter. In general today, I believe there are only these two types, the cup meter and the propeller wheel meter that are used to any extent at all.

Q. Does the cup meter adjust itself to varying directions in the current as readily as the Haskell meter?

A. I believe it does, from my own observations and the use of the cup meter.

Q. Just what preliminary test did you make of this meter that was used there?

A. By preliminary test, what do you mean, these tests themselves?

Q. No, to rate the meter and so on, if it was rated.

A. We rated the meter in the way it is usually done on our canal. We have a rating station there. The canal is spanned by a car which is operated electrically and we are able to get velocities from about a half a foot a second to possibly eight or nine feet a second.

Q. What is that, a still water rating?

A. Still water rating, yes.

Q. How long before your test, to which Mr. Schoder has testified, was that rating made?

A. I can't tell without referring to the data. I haven't them here. The tests were made before, during and after these experiments; the rating of the meters.

Q. Was there any change whatever in the condition of the meter at any of those times when you made ratings?

A. No, those ratings all seemed to fit the same general line.

Q. Was that the only test you made as to the accuracy of the meter, the still water rating?

A. That does not test the accuracy, as I see it, the still water rating. That is simply a means of finding something by which to interpret the indications of the meter we actually used in discharge measurements.

Q. Did you make any test to test the accuracy of the meter?

A. Only these tests themselves.

Q. You did not, for instance, test the meter with particles in the water, anything of that kind?

A. No.

Q. I believe you say you used a pole to hold it with?

A. Yes, it was held from the bridge by a rod.

Q. Did you have a lead standard?

A. No, what was known as a foot plate on the meter; no lead weight under it. The photograph of the meter shows the condition in which it was used; shows the condition of the meter, rather, while in use.

Q. How long is the canal from the baffles; how long is your canal from the baffles?

A. I can't state exactly; in the neighborhood of 350 feet, possibly a little less.

Q. What is the condition of the canal, say at the lower end of it?

A. The sides are rough, due to the cement coating being off in places. The bottom is smooth; that is the original cement bottom is the same as when it was first constructed. The sides are rough because of this coating having fallen off.

Q. Is that true pretty well along the canal?

A. Along the sides. The bottom is still smooth.

Q. Your photographs show that, don't they?

A. I believe they do. I can't say for certain.

Q. Is there any difference between the condition of the canal at the lower end and at the middle, say?

A. Not any that the eye would detect, that is any general conditions. There may be little spots here and there where the side is smoother, but in general it is about the same.

Q. Why weren't some of these readings made further down than 250 feet?

A. Well, taking my estimate of the whole distance from baffles to the lower end, 350 feet or thereabouts the water which passes under the weir—(the weir was raised at the lower end of the canal) as it approaches that point, begins to acquire very high velocities, so that if we got down in the region of the actual discharge point itself in the canal, we would get into pretty extreme conditions of velocity.

Q. What would you call very high?

A. Well, I should say anything up in the region of the upper limit of ratings, seven or eight feet a second, eight or nine feet a second. What I am speaking of now refers only to the measurements with which I had anything to do; that is the first five. I was not connected with the last four measurements.

Q. The first five were all made within the extreme limits of distance from the baffles, weren't they, the first one 51 feet?

A. The distances are all stated. I do not recall them.

Q. And the second one was 260 feet?

A. 260.

Q. From the table furnished by Mr. Schoder, there is no velocity at the second measurement, which is 260 feet down, higher than three feet. Does the velocity increase after that?

A. It would down in the region where this water leaves the canal.

Q. Wouldn't the conditions a little further down, where the velocity begins to increase, give a more even flow though, rather smooth out the roughness gotten from the fall above?

A. No, I should say under certain conditions the flow there might be radically different from that, because if the discharge was not flowing freely under this weir that was raised, that is, the weir jutted down into the stream, there would be high disturbance.

Q. What weir are you speaking of now?

A. The bulk head at the lower end of the canal, which was raised during these experiments.

Q. Would that raising it at the lower end tend to retard the flow in the canal or increase the flow?

A. That would depend—it would increase the velocity of course, but diminish the depth. In order to get a fairly high velocity, this lower weir was raised so that the water could flow freely under it.

Q. In that 350 feet, you have a condition where the velocity in the first 50 feet or so, at 50 feet you have a velocity running up nearly six feet a second, and 260 feet it is below three feet a second. And then it gets faster again?

A. I can't recall the figures, but I know originally—

Q. Assuming they are correct? I am taking them from figures furnished by Mr. Schoder.

Q. That might be for a measurement, yes.

Q. Under such conditions as that, what place in the canal would be the best to get accurate measurements?

A. Well, so far as the eye could detect, any reach between that 260 point and 100 or more feet upstream would look equally good.

Q. How about 100 feet further down stream?

A. That would lead you outside the canal itself.

Q. I thought it was 450 feet along?

A. About 350 I think. I might add that the canal is arranged for making observations at the 260 foot point; there are ladders on which bridges can be placed at that station. That was of course one of the reasons why that point was selected.

Q. Professor Haskell did not take any part in any of these tests?

A. I don't think he came over during the measurements at all. I didn't see him.

Q. Did he follow the work?

A. I don't think so. He never said anything to me about it.

Q. Where do you measure this water that went through the canal, by the weir above or below?

A. In these experiments the flow was measured by a weir that was above the baffles.

Q. How was that weir calibrated?

A. That weir is an experimental weir which Professor Schoder and I have been using for some research work for some time past, and the water that flows over that weir in our observations is passed over the weir at the lower end of the canal.

The weir at the lower end of the canal is duplicated inside the laboratory in a smaller canal, as to height, character of crest and so on; and we have a means of getting volumetric measurements of the flow over that weir that is in the laboratory, so that by tying the weir at the lower end of the large canal in with that, and tying that weir at the lower end of the canal with the upper weir, we are able to calculate for flows that do not go beyond the range of head of experiments on the weir in the laboratory.

Q. Then the weirs in the canal are not calibrated at all?

A. In that way that I just stated, not volumetrically absolutely.

Q. By using one of similar shape in your laboratory?

A. One with similar conditions as regards the height of the weir and the character of crest and so on, yes.

Q. You have no absolute measurements then, or actual calibration of these weirs, have you?

A. We have no volumetric measurement of the weir itself; that is the one at the lower end of the canal.

Q. If your method of transferring your observations from one weir to another should happen to be in error to a slight extent, and there was error in your method, that error would usually show on the same side?

A. Oh yes, if there were error in the method, that would prevail, of course.

Q. You said this morning you thought that error was well within one per cent.?

A. Yes.

Q. Might that not be even larger than that?

A. Not to the best of my knowledge.

Q. You have no way of checking it though absolutely, have you?

A. In the way I have stated already, that is all.

Q. Simply by a model?

A. By a model with exact duplication of the conditions.

Q. Different size?

A. Different only from the standpoint of length; otherwise the same.

Q. At each cross section you made measurements at 13 places, didn't you?

Q. That is in the thirteen vertical positions; 13 positions across the stream?

Q. Yes?

A. Yes, something like that.

Q. And the one nearest the bottom was half a foot from the bottom?

A. I don't recall whether they all were, whether all the bottom measurements were at that depth, but I know they were on some of the runs.

Q. And from the sides you began within half a foot?

A. Half a foot from the wall, yes.

Q. How would you explain this difference between the measurements of the current meter and the measurements you had over the weir?

A. Well, one explanation which I believe would apply would be that the meter while in use was vibrating to a considerable extent in a horizontal plane, and in a vertical plane also, and I think that vibration would tend to introduce discrepancies in the observations.

Q. That water was at rather a high state of perturbation, wasn't it?

A. It was in a state which caused the meter to vibrate, as I stated.

Q. Wasn't the water in that canal much more perturbed than an ordinary river, or the rivers that we spoke of, the Niagara and St. Clair?

A. Not at the lower stations, that is so far as the eye can judge. Of course that is merely a relative matter. You have to judge from appearances. Beyond the very first station next to the baffles, that is from there 40 or 50 feet downstream, the eye would not detect much difference in the appearance of the flow. After the foamy part of the first overfall from the upper weir had gotten out, the character of the flow had gotten fairly settled, so far as the eye could see.

Q. Were there any other uncertainties of measurement?

A. I don't know of any.

Mr. Adcock: I object to that question, because it assumes

that there were uncertainties, and it has not been shown that there were.

Mr. Hopkins: Q. There was an uncertainty in the weir itself, wasn't there?

A. As I have stated, there was an uncertainty which I believe was less than one per cent.

Q. There was an uncertainty in the cross section of the place in the canal that you were using, wasn't there?

A. I should say that is under 1/10th of 1 per cent., it was very accurately measured both horizontal and vertical by tape.

Q. Up near the baffles, where it was rough?

A. You mean the cross section of the stream itself?

Q. Yes?

A. Measurements were made across the section every foot by what is known as a point gage, that is a long staff with a point on the end, which was lowered down from the bridge and the average position of the water surface read at each point and the average of all those readings was taken as the average water level for a measurement, for a discharge measurement.

Q. What was the variation in level across the width of the stream, say within 75 feet of the baffles?

A. I can't tell without referring to the record.

Q. Is that in any of these papers that has been handed me here?

A. No, I don't think so. That is you refer to the average level? Of course these reports of levels taken were averages of the position of the water surface.

Q. What would you say would be the extreme between the lowest and the highest?

A. Based on my recollection, I should say maybe two-tenths of a foot, possibly one-tenth. It might be as much as two-tenths, but I should say more likely one-tenth.

Q. Wasn't there a kind of choppy, wave motion all the way through to the crest at the valley there?

A. At the upper section?

Q. That is what I am speaking of.

A. Yes.

Q. So that it made it very difficult to measure the cross section of the stream?

A. No, I don't call it difficult to get the cross section, the average cross section under such conditions.

Q. There is kind of a retardation in the flow of a stream

next to the bottom and at the sides, say, of a canal of this kind, isn't there?

A. There is considerable; not so much as one would find in a rougher stream. This is a smooth bottom, of course, smooth cement bottom.

Q. Just how did you compute your volume from the measurements that you had at any particular cross section?

A. The observations for velocity were first gotten, of course, in the form of revolutions of the meter.

Q. In the form of the readings as you have here?

A. Those are the summary of results.

Q. After you had those?

A. From the readings of the meter the velocities in feet per second where the readings were taken were found from the rating curve, rating table. Then the stream was divided into vertical strips in which the mean velocities in the verticals controlled each its own proportion of the whole area and by the kind of calculations used in stream measurements, the partial discharge for each strip was found; the sum of those giving the discharge for the whole stream.

Q. To what extent did you take into consideration the difference in the velocity next to the walls and next to the bottom?

A. In taking the velocity near the wall, the nearest of course that we could get by virtue of the construction of the meter and its size was half a foot; and we assumed that that observation controlled a one foot strip; that is the first foot of width. And the same way at the bottom, we assumed the observation 5/10ths from the bottom controlled the last foot of depth.

Q. There is quite an area there around the sides and next to the bottom that you could not measure because of the meter, wasn't there?

A. Yes, the nature of the meter was such we could not get nearer than that.

Q. It was to some extent uncertain, and you had to assume the flow in some such way as you have mentioned?

A. Yes. We assumed that the drawing back in the velocity on the bottom was much less in the case of this smooth canal than it would be in a stream, and the best assumption based on data available was that those velocities would control one foot of width and control one foot from the bottom.

Q. You had to use some theories then?

A. Yes, we had to make some assumptions as always is done in such cases.

And there is always a possibility of an error?

There always is, so far as that partial discharge is con-
ed. The error is slight, of course, in connection with the
e.

In a canal, shallow canal, besides running up straight
way (illustrating), the percentage of the total flow that
this indeterminate area is much greater than in a big
, isn't it?

I should not say it was. I should not say any more
r is introduced by virtue of conditions that obtained in
canal than in the case of a stream, ordinary stream.

Your average of the depth here as shown in these
urements is less than four feet?

Those five with which I had to do were less than four
yes. I believe that is the figure.

And certainly in a shallow stream, there is a greater
ortion of this indeterminate area to the whole volume
in a deep stream, isn't there?

Oh yes, there would be.

In fact it would be nearly 25 per cent. of the total
me?

Nothing like it, I should say. Four feet, and half a
would mean only 1/8th.

Half a foot at the top and half a foot at the bottom?

We can measure within a little less than half a foot
e top. You cannot with the Haskell meter; you can with
other types.

That is what you were measuring with here?

Yes.

The point I am trying to bring out is if there is an
r in this indeterminate area in the shallow stream, the
entage reference to the whole will be greater than in a
er stream?

It might be, yes.

Yes, might be. If there is an error, wouldn't it be?

No, I don't think it would, because in this same canal
have run numbers of experiments with smooth flow, that
ithout trying to introduce disturbed conditions of any
, and have found that our measurements checked the
very closely. Now if we made large errors as regards
conditions near the bottom and the wall in the one case
vere made in the other, we ought to get the same dis-
ancy.

If there is an error in your theory—you have a theory,
ssuming this that I call the indeterminate theory?

A. Yes.

Q. If there is some constant error in that theory, wouldn't it be greater in volume in a shallow stream than in a deep stream?

A. Yes, you can measure more accurately of course, relatively in a large stream than you can in a small one, providing you use the Haskell Meter.

Q. Your only criticism of this Haskell Meter is that there is an error in the instrument itself due to perturbed condition of the water, and resulting in an under registration?

A. I should say that is what the tests bear out, yes. The under registration of course is helped (lessened) by our assumption as to the velocity at the walls and the bottom, because in an ordinary stream we know the velocity draws back more than we assumed in this case, so that we really gave more flow than we would had the case been that of a natural stream.

Q. That depends on your theory, doesn't it?

A. There is no theory involved.

Q. I believe you said the bottom of this stream was very smooth?

A. Yes.

Q. So that there would be much less retardation there than there would be in an ordinary stream?

A. There probably would be.

Q. From what can you say that you took that into consideration sufficiently in your estimate?

A. By looking at the curves of vertical velocity, which are plotted on one of these sheets.

Q. But the curves might make a radical change within that limited area, as it approaches the bottom or approaches the station?

A. Yes, I think if we could have made Pitot tube or other current meter observations, we would have found a greater drawing back than was used in computing the experiments.

Q. Then your test was not the most accurate, according to your best judgment?

A. The most accurate that we could make under the given conditions.

Q. You think you did not allow sufficiently though for the retardation?

A. I think that whatever doubt is involved is in favor of the meter rather than otherwise.

Q. You say you have measured streams when the con-

ditions were more favorable, smooth or something of that kind?

A. Yes, we have made experiments in the same canal with small flows, the velocity more uniform.

Q. What meter did you use?

A. Both the Haskell and the Price meter.

Q. How did the results check with the weir?

A. Very closely, within one per cent. usually.

Q. With your uniform velocity?

A. Not exactly uniform, but a more uniformly varying velocity from top to bottom; more nearly like normal conditions in a stream.

Q. You say then they checked within one per cent.?

A. I recall numbers of observations which checked that way, yes.

Q. What was the velocity in some of these conditions, where they did check?

A. That I can't say offhand.

Q. Do you have any idea of any limits?

A. It might be from two to four or five feet a second possibly.

Q. So that these tests were made under highly artificial conditions, that is as regards perturbation of water?

A. Highly artificial as regards to the canal; we have not run tests of that character before.

Q. At whose instigation did you start into this testing?

A. Professor E. W. Schoder. Professor Schoder had charge of the tests, and arrangements were made with him.

Q. I believe you said you did not know the condition of flow in the rivers that the Lake Survey have been making measurements in, with the exception of the St. Mary's?

A. Not in the St. Clair or the Niagara, which were mentioned.

Re-direct Examination by Mr. Adcock.

Q. This hydraulic laboratory which is composed of this canal and other apparatus, etc., is used for the purpose of making experiments by various people in the country, is it?

A. Yes, commercial tests are made there very frequently.

Q. United States Government has made tests there?

A. They have made tests.

Q. In connection with their work?

A. I had nothing to do with it at that time. It was before my time.

Q. And this weir, and calibrating the weir, etc., and this laboratory are maintained by the College of Civil Engineering of Cornell University?

A. By Cornell University, of which the Engineering College is only a department.

Q. You say that Professor Haskell—

A. He is director of the College of Civil Engineering.

Mr. Adcock: That is all.

Whereupon an adjournment was taken subject to notice.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the rooms of the Sanitary District, Chicago, Tuesday, January 20th, 1914.

Appearances:

Mr. James H. Wilkerson and
Mr. Albert L. Hopkins,
Representing the Government.
Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
Representing the Sanitary District.

GEORGE M. WISNER, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?
A. George M. Wisner.
Q. Where do you reside Mr. Wisner?
A. Chicago.
Q. What is your business?
A. Civil engineer.
Q. Are you connected with any municipal or commercial concern?
A. Yes, sir.
Q. What are your connections at the present time?
A. Chief Engineer of the Sanitary District of Chicago.
Q. With the defendant in this case?
A. Yes, sir.

Q. How long have you been acting as Chief Engineer of the Sanitary District?

A. I think since 1907.

Q. Prior to that time what was your engagement?

A. Well, I started in, in 1892, as a rodman, I think, and then was made sub-instrument man, instrument man, sub-assistant engineer, assistant engineer, assistant chief engineer, and then chief engineer in 1907.

Q. What are your duties as Chief Engineer of the Sanitary District?

A. I have entire charge of all work coming into the engineering department, which involves the design of all the works carried on by the Sanitary District; and in charge of the construction of works that are in process of being built. I am also in charge of all the original research carried on by our experimental stations. This applies particularly to sewage disposal and water purification.

Q. Will you state your education and experience to qualify you to practice as a hydraulic and sanitary engineer?

A. I had the ordinary school education; graduated from the Detroit High School and entered the University of Michigan in the fall of 1888; and graduated in civil engineering in the spring of 1892. Then went to work, a few days later, for the Sanitary District. My duties there involved a study of sewage disposal and sewage conditions, as well as all sorts of construction work. It also involved, and caused me to study and look up all hydraulic problems, many of which enter into our work here. In the matter of sewage disposal, I have visited the plants at Columbus, Baltimore, Milwaukee, Washington and other American cities. I have visited the plants at Birmingham, Manchester and London in England; Paris, France, and Berlin, Germany; possibly one or two others which I have forgotten.

Of course this has involved the reading of authorities on this subject and the consultation with other engineers engaged in similar lines of work, which has tended to keep me informed as to the progress of the art up to the present time.

Q. Has your connection with the Sanitary District of Chicago enabled you to become familiar with the various works of the District?

A. Absolutely.

Q. All of the works of the Sanitary District have been installed during your service with the defendant?

A. All of them. I was at work on the construction work

at the time of the shovel day; that was when the first spade full was turned on the construction of the main channel.

Q. Are you familiar with the sewerage system of the City of Chicago?

A. Yes, sir.

Q. Will you describe briefly the essentials of the sewerage system of the City of Chicago and the Sanitary District, and point out in particular the location of the present intercepting sewers, which divert sewage from the lake. I show you a map which I offer in evidence, the same showing the limits of the Sanitary District of Chicago, which may be marked Wisner Exhibit 1, January 20, 1914. And in that connection will you also describe the map which I have just shown you?

(Map shown to witness and offered in evidence by counsel for defendant was here marked Wisner Exhibit 1, January 20th, 1914.)

A. The sewerage system of the City of Chicago consists of sewers built for the collection of sewage; the first one being built in 1855, and they have been added to since, piece by piece. They range in size from six inch tile up to brick sewers 20 feet in diameter. The more important sewers are those that are two feet in size and over, as shown on Wisner Exhibit 1.

The sewers originally discharged into the Chicago River, and a part of them, on the north and south sides, directly into Lake Michigan. The sewers are all built on what is known as the combined system; that is they receive both the storm water and the sanitary sewage; all the sewage coming directly from the homes and buildings of the city. They also receive to a large extent the manufacturing wastes.

There have been completed recently two main intercepting sewer systems. These were built by the City of Chicago to prevent the sewers that had previously discharged directly into the Lake from discharging into it; in other words to keep the sewage out of the lake. One is on the North Side, and is shown on Wisner Exhibit 1, starting on the north at Howard avenue and running south to Lawrence avenue, and a part of the same system starting on the south at Diversey boulevard and running north to Lawrence avenue, where the sewage is picked up by pumps and forced through a conduit 16 feet in diameter on Lawrence avenue to the west and into the north branch at that street. This pumping station also pumps diluting water from Lake Michigan, mixing it with the sewage water,

and being utilized for dilution of the sewage and flushing the North Branch.

The other intercepting sewer system is on the South Side, as shown on Wisner Exhibit 1, and extends on the south from 87th street north to 39th street and the lake, and from 31st street south to 39th street, preventing the sewage which had flowed directly into the lake from flowing therein. At 39th street it is picked up by pumps and forced through a 20-foot conduit west to Halsted street, where it discharges into the east arm of the south fork of the south branch of the Chicago River. This is the arm of the river that is commonly known as Bubbly Creek.

The same pumping station pumps fresh diluting water from the lake, diluting the sewage and flushing out the arm of the south fork of the south branch. This combination of fresh water and sewage flows through the south fork to the south branch; then into the west fork of the south branch, and then directly into the Sanitary Canal.

Other sewers north of 31st street and south of the main branch of the river that had discharged into the lake have been reversed, and the sewage now flows directly into the river. The result of all this work has been that no sewage between the south line of Evanston and the Calumet River enters Lake Michigan at this time.

The sewers between the main river and Diversey boulevard prior to the works of the Sanitary District, did not discharge into the lake, but either discharged into the main river or the north branch and required no reversal of the sewage flow to keep the sewage from getting into the lake.

Q. Did not require any intercepting sewers to be built?

A. No.

Q. And those sewers discharge in the same way that they did previously?

A. Yes, sir.

Q. Will you describe the present water supply system of the City of Chicago, and point out the location of cribs, and their position?

A. The water supply system of the City of Chicago has been developed since 1852. The city takes its water supply directly from Lake Michigan by tunnels which extend out beneath the bottom of the lake to cribs or intakes. These tunnels and intakes and the water supply system is maintained by the City of Chicago. The present cribs are from two to four miles off shore, and are shown on Wisner's Exhibit 1.

There are six of these cribs. The first one, known as the Two Mile Crib, was built in 1867, and is opposite Chicago avenue on the North Side. The Four Mile Crib, built in 1892, is, as indicated, approximately four miles off shore and is opposite 14th street.

The Hyde Park Crib was built in 1894, and is practically two miles off shore opposite 68th street.

The Lake View Crib built in 1896, is two miles off shore and opposite Montrose avenue, or boulevard.

The Carter H. Harrison Crib was built in 1899, and is three miles off shore; practically amounts to the extending of the old Two Mile Crib, although I believe at times both are used. It is opposite Chicago avenue.

The Dunne Crib built in 1910, is two miles off shore and opposite 68th street. It is right alongside of what is known as the Hyde Park Crib. It was put in to give additional capacity for this particular part of Chicago that those two cribs serve.

I might say that this water, after passing through these tunnels under the lake is then carried by land tunnels to pumping stations located in different parts of the city, and forced through the mains to consumers.

Q. Will you describe the various works of the defendant built and operated for the purpose of protecting the water supply of the inhabitants within the limits of the Sanitary District?

A. As preliminary to the answer to that question, I would state that I will not re-describe the sewerage system which has already been spoken of in previous answers.

The Sanitary District was organized in 1889, and the construction was started in 1892. The principal feature of its work has been the construction of what is known as the Main Channel. This channel begins at Robey street and the Chicago River, which is about 6 1/3 miles from the mouth of the river. It was originally 28.05 miles long and extended from Robey street the starting point to Lockport, Illinois. Practically the first 14 miles of it was through clay and glacial deposits, and the lower 14 miles was through limestone rock.

The Chicago end of the canal, for about 7 miles, was constructed to about half of the ultimate capacity. It was capable of progressive development as the needs for additional water became necessary to dilute the sewage. This extended to a place known as Summit.

From Summit to Willow Springs, a distance of another 7

miles, the channel was constructed to its full capacity; and from Willow Springs to Lockport, through the rock, it was constructed to its full capacity.

The channel at the upper end was 110 feet wide on the bottom, and had side slopes of one vertical on two horizontals.

The second stretch through the glacial deposit to Willow Springs was 202 feet wide on the bottom, and with the same side slopes. From Willow Springs to Lockport, generally, the channel was 160 feet wide on the bottom, and 162 feet wide on the top, with sides that were practically vertical.

At the end of the channel were controlling works for regulating the amount of water flowed through the Chicago River and the Main Channel.

In 1903, the right was obtained from the Legislature to develop power which had been incidentally created in connection with this work, and the channel was extended to practically the City of Joliet. Prior to this, however, the Sanitary District had done considerable work improving the Des Plaines River below the end of the Main Channel and through the City of Joliet, removing several dams and deepening the stream, building levees and walls. This power development involved the lengthening of the upper reach of the Main Channel for about two miles, at which point was located a power house, dams for regulating the flow and a lock for the passage of vessels from one level to the lower level. It developed an average head of about 34 feet, and the plant is capable of developing about 4,000 kilowatts for every 100,000 cubic feet of water flowed per minute; generally, in round numbers, that is true.

Below the power house, the channel is carried on the same depth, practically the same depth as above the power house, which I neglected to give, it being about 24 feet at normal stages of the lake, to a point near to the upper limits of Joliet, where it is from there through the City of Joliet ten feet or over in depth. This power extension was completed I think in the latter part of 1907 or early in 1908. If it is important I can get the exact date.

Q. It was the later part of 1907.

A. I think that is right.

Q. It was put in operation December 31, 1907?

A. Yes, I believe that is right.

This work involved the construction of transmission lines and distributing systems in the City of Chicago, most of the power being brought to Chicago for the lighting of streets

and pumping of water for the municipality, the excess being sold for commercial purposes. This power was all developed incidental to the sewage disposal, and the District has never flowed more water on account of power developments than it would have flowed if there had been no development there. Prior to this construction this power was simply going to waste, and it simply amounted to the conservation of this wasted energy.

In connection with getting water through the Main Channel, it became necessary, on account of the restrictions placed on the velocity of the current in the South Branch for the Sanitary District to improve the South Branch of the Chicago River by widening and deepening it and by the removal of certain bridges, whose center piers interfered with the free passage of the water through the river.

The Sanitary District has expended approximately $11,-500,000, on the improvement of the Chicago River. This money was expended almost entirely under what is known as the 1900 Project. It generally was expended to widen the South Branch from its junction with the North Branch at Lake street to the beginning of the Drainage Canal at Robey street. The river has been widened to a width of at least 200 feet, and it has been deepened so that at the dock lines there is a depth of water of 16 feet, gradually deepening to a point 50 feet out from the docks where it is 26 feet deep for the middle 100 feet of the river. This depth of water is below what was known as the hydraulic grade of the river; that is the water in flowing from the Lake to the Drainage Canal has a slope which at times is two feet lower at Robey street than the Lake level.

This widening of the Chicago River involved the purchase of over 792,000 square feet of property along the Chicago River, and generally, I should say, the river had been widened on an average 50 feet. The widest piece taken off was, as I remember, 110 feet in width, and from that down to nothing.

This involved the excavation of over 5½ million cubic yards of material; the construction of over 19,000 lineal feet of dock, for wherever the Sanitary District widened the river it became necessary to build new docks.

In the improvement of the river, as already stated, the Sanitary District replaced many of the old center pier bridges with bridges of the modern type, known as bascule bridges. It has replaced or rebuilt the following bridges across the Chicago River: State street, Dearborn street, Randolph

street (and it is now engaged upon the construction of a new bridge at Jackson boulevard), Harrison street (Polk street was built by the City of Chicago), Taylor street, Chicago Terminal Transfer Railroad Bridge, now owned and operated by the Baltimore & Ohio Railroad (it has agreed to pay half the cost of rebuilding the 12th street bridge, which has been ordered out by the Secretary of War), 18th street, Canal street, 22nd street, Main street, Throop street and Ashland avenue. One other bridge was removed and reconstructed by the City of Chicago. That is at Washington street.

Widening the river also involved the removal of many buildings, and paying damages to adjacent property owners.

The Sanitary District has also widened and deepened the North Branch of the Chicago River from Belmont avenue to Lawrence avenue, a distance of about two miles. This stream, prior to this straightening and deepening, was practically dry in the summer time, simply being a small creek. The Sanitary District made a stream having a depth of 12 feet and a width of 90; and has also deepened the South Fork of the South Branch to a depth of 20 feet; has done considerable work in the West Fork of the South Branch west of the beginning of the Main Channel, deepening it about three feet.

This, generally, covers the work done by the Sanitary District as far as its main channel and the Chicago River are concerned, with the possible exception of the North Shore Channel which was completed in the latter part of 1910 and early in 1911; and it extends from Wilmette and the Lake to the North Branch of the Chicago River at Lawrence avenue. This was a rather small canal, having about 13 feet of water. It is navigable and was built to take care of the sewage coming from what is known as the North Shore towns, that is the towns from Glencoe south to the Chicago Limit, including Evanston, Wilmette, Winnetka, Kenilworth and Glencoe. It is provided with a pumping plant at Wilmette, which pumps 1,000 cubic feet of water per second through this canal and down into the North Branch, and the water to be used for diluting the sewage and flushing out the North Branch, which otherwise would be stagnant, septic, and become a local nuisance. This water flows then directly into the South Branch and into the Drainage Canal.

Q. What was the depth of the South Branch of the Chicago River before the Sanitary District entered upon the project of deepening and widening?

A. The South Branch had been dredged by the United

States Government to a depth of 17 feet, but it had shoaled up considerably, due to silt coming in from the lake and settlement coming from sewers, so that at the time the District started on the deepening of the South Branch, it did not have available probably over 16 feet.

Q. You spoke of a lock at Joliet, the terminus of the Sanitary District Channel. Is that capable of being enlarged, are facilities provided so that it could be enlarged to accommodate very large vessels?

A. It is not the intention to enlarge that lock, but there was space left, and the work was so designed that a large lock could be installed when the deep waterway is constructed.

Q. What is the depth of the water now through the various branches of the Chicago River and Drainage Channel to the terminus of the Drainage Channel at Joliet?

A. The Chicago River through the main river is 20 feet; through the South Branch and West Fork down to the main channel 26th street. The main channel itself at ordinary stages is at least 24 feet as far as the power plant. Below the power plant it is 20 feet to the north limits of Joliet, and from there on at least 10 feet in depth down to Dam Number 1, which is near the center or heart of the city of Joliet. Below there the Des Plaines River is not navigable. The only means of navigation from there on at the present time to the Illinois River is by way of the old Illinois and Michigan Canal.

Q. Do you know how much the United States has expended in the improvement of the harbor at the mouth of the Chicago River?

A. It has expended approximately $2,390,000. No part of that sum was expended in the improvement of the Chicago River. The Government did not expend any money in connection with the improvement of the Chicago River until 1896.

Q. Since 1896, what has the United States expended, up to say June 30, 1913, in the improvement of the Chicago River itself?

A. Approximately $1,626,000.

Q. Do you know what this money was expended for in the Chicago River?

A. It was expended for dredging the North and the South Branches to a depth of 17 feet on the first project, and later the deepening of the North Branch as far north as Belmont avenue, I think, to a depth of 20 feet.

The Government also bought some land on both branches of the river for the purpose of constructing what is known

as turning basins. These are basins that are large enough so that vessels can turn around and come back down the river bow first. The one on the North Branch is at Diversey boulevard, and the one on the South Branch is at the junction of the West Fork and the South Branch, just east of Ashland avenue. Part of this money on the original project was expended for widening the Chicago River at some of the narrowest and most dangerous places. Part of this money was expended deepening the main branch of the river to a depth of 20 feet from the mouth to the junction of the two branches. Generally this covers the money that was expended by the Government for the improvement of the river.

Q. Do you know how much money the City of Chicago has expended in the improvement of the Chicago River?

A. Approximately $6,275,000.

Q. Do you know what it was expended for; and between what years?

A. I think from about 1861 to the present time, approximately to this time. It was expended for dredging of the Chicago River, both the main river and on all its branches, building of bridges and docks, and general improvements.

Q. Were any of these improvements in the Chicago River done by the United States Government during the time that the Sanitary District was completing its works?

A. Yes. I refer particularly to the South Branch. The deepening of the North Branch has been done in quite recent years; that is deepening the North Branch to 20 feet.

Since the 17 foot project of the United States Government it has done no work on the South Branch, although it has deepened the North Branch to 20 feet. The Sanitary District took up its work and did this dredging. When the Sanitary District started on this project, the Government had, as I recall, not quite completed the dredging to 17 feet. And I know it was widening the river at certain places where it was narrow, that is the South Branch. Some of this work of the Government and the Sanitary District was carried on simultaneously. The widening done by the Government however was at a few places, and did not amount to very much.

Q. The Sanitary District commenced its work on the improvement of the Chicago River along about 1896, did it not?

A. Yes, along about 1896 or '97.

Q. Will you state the conditions of navigation upon the South Branch of the Chicago River prior to the time the Sanitary District widened and deepened it, as you have stated?

A. Boats drawing over 16 feet of water could not have navigated the South Branch, even providing that the tunnels had been removed, for the reason that there was not any more available depth than that, up to the time that the Sanitary District started its dredging. I do not believe that a boat over 400 feet in length could have navigated beyond 22nd street, for the reason that between 22nd and Halsted street the river was very narrow and tortuous, and a boat of that length could not make the turn. Boats having a beam greater than 48 feet would probably not have been able to pass through some of the bridge openings. These bridges have since been removed and replaced by modern bridges giving a wider opening.

Q. What are the conditions of navigation as the result of the Sanitary District improvements in the Chicago River?

A. Well, at this time I think a boat of probably 500 feet could navigate the river, and one drawing 20 feet; the depth being controlled by the depth in the main branch of the river. If certain bridges, which are now either coming out or shortly to come out are removed, a boat of larger length could be taken down the river.

Q. What flow of water will the Chicago River in the South Branch accommodate without injury to navigation?

A. The critical point probably, the critical stretch, is from Lake street to the turning basin at Ashland avenue. This will safely take, in my opinion, 8,000 cubic feet a second. From there on to the Drainage Canal, the river is much wider, and with the same depth would take an additional flow of water without any injury to navigation.

Q. Would the current exceed 1¼ miles an hour through that stretch?

A. No, sir.

Mr. Hopkins: You mean after you pass Ashland?

Mr. Adcock: No, through the stretch.

The Witness: Anywhere.

Q. Have you described all of the works of the Sanitary District, so far?

A. I think I have described the principal ones. The Sanitary District has done some work in improvement on the Illinois River, and some improvement in a sanitary way for some of the smaller towns within the limits of the Sanitary District.

I have assumed that in describing the sewerage system and speaking of the pumping stations which were constructed by

the City of Chicago, that they are part of the works of the Sanitary District. Certainly 39th street Pumping Station is, where the Sanitary District paid quite a percentage of the cost.

Q. I show you Exhibit B to the answer in this case and ask you whether that is a correct representation of the position of the Chicago River and its various branches with reference to the limits of the Sanitary District?

A. Yes, sir, it is; on a very small scale, however.

Mr. Hopkins: That is to the answer in number 114.

Mr. Adcock: Yes.

Q. What is the area of the Sanitary District as it exists to-day?

A. The total area of the Sanitary District is at the present time 386.2 square miles. The original Sanitary District, that was up to 1903, was 185 square miles. The North Shore District of 78.6 miles was added at that time, as was what was known as the Calumet District amounting to 94.5 square miles, and under a recent act of the Legislature 28.1 square miles more have been added to it. This includes all of the City of Chicago, the area of which is a little over 191 square miles. The total is 386.2 square miles.

Q. I show you a map which I offer in evidence and ask that it be marked Wisner's Exhibit 2 of this date. I wish you would explain that map.

(Map offered in evidence by counsel for the Sanitary District was marked Wisner's Exhibit 2, January 20, 1914.)

A. This is a map that was prepared in this office under my direction. It is a map showing the land sections of Cook County, part of DuPage County, a part of Will County; and generally shows and was made to show the areas comprising the Sanitary District with its relation to the Chicago River and the main Drainage Canal. There is a scale upon this map. The part of the map which is tinted green is the original Sanitary District. The part lying to the north of this and tinted a brown is the area that was added to the Sanitary District by the Legislature in 1903; and the part lying to the south of the green tint and tinted brown is what is known as the Calumet Extension to the District, and was added in 1903.

The part tinted brown and lying west of the green tint is that which has been added to the District recently. The yellow tint shown upon this map indicates the branches of the Chicago River and the Main Drainage Channel extending to Joliet.

The part tinted red, or red line, and marked Calumet-Sag Channel is the Calumet-Sag Channel which is now being constructed from the Little Calumet River, east of Blue Island to the present main drainage channel at the place marked Sag.

Q. Did you mention in your description of the works of the Sanitary District the Fullerton avenue conduit?

A. That was built by the City of Chicago prior to the Sanitary District work, and is a conduit extending from Lake Michigan to Fullerton avenue and the North Branch; was installed for the purpose of flushing the North Branch.

Q. You mentioned the Sag Canal Project. Will you describe that and state the condition of the work to date; and what relation it bears to the entire project?

A. I overlooked in my former answer a description of the Calumet Sag Channel. It is a channel extending from the Little Calumet River just east of Blue Island to the Main Drainage Channel at the Sag, a distance of approximately 18 miles. It is a channel which is to have water 20 feet in depth, and through the rock sections is 60 feet in width, and through the earth sections generally 36 feet in width on the bottom, with side slopes varying from one vertical to two horizontal, to flatter slopes.

It is to have regulating and controlling works located at its eastern end, which will control the amount of water that can flow through it. Generally it is designed to carry 2,000 cubic feet per second at this time, but it is capable of progressive development so that it can ultimately be enlarged to carry at least 4,000 cubic feet per second. And it has been my intention to enlarge it to that capacity, when it became necessary. It was not done at this time for the reason that it figured cheaper to make this progressive development than to make a large initial investment, which would not be needed for some years to come.

At the present time, this work is under construction, there being nine contract sections awarded by contract averaging about a mile and a quarter long; there are about five more to be let within the next few months.

This canal will be navigable.

Q. What city, villages and towns are located within the limits of the Sanitary District?

A. Chicago, Evanston, Glencoe, Winnetka, Wilmette, Shermerville, Glen View, Morton Grove, Niles, Cicero, Stickney, Evergreen Park, Morgan Park, Blue Island, Riverdale,

Oak Park, Berwyn, Forest Park, River Forest, Maywood, Riverside, Brookfield, Bellwood, Franklin Park, Melrose Park, River Grove, Dolton, Harvey, West Hammond, Worth, Bremen, Calumet, Kenilworth, Burnham.

Q. Will you describe the Chicago drainage area and state the amount of the run-off of that area?

A. The drainage area of the Chicago River basin is about 307 square miles. The run-off of the Chicago River basin in a dry season is practically the city water supply, and some little ground water, but at times of maximum floods it will reach as high as 10,000 cubic feet per second.

Q. Have the inhabitants of the Sanitary District within the boundary of the Sanitary District any available water supply other than Lake Michigan?

A. Generally, no. It would be impossible to supply the entire inhabitants of the Sanitary District with a good supply of water by any other means. There are a few wells in Chicago and the smaller places, which are used for that purpose; but it would be impossible to get sufficient water from a ground supply to supply the entire city.

Q. What was the condition of the Chicago River and Lake Michigan in reference to pollution, etc., prior to the opening of the Drainage Channel?

A. To illustrate what the appearance of the Chicago River was at that time, it is only necessary to say that practically the entire North and South branches were in the same condition as that part of the Chicago River known as Bubbly Creek is at the present time. It was a filthy, dirty sewage polluted water, in a septic condition, with gas bubbles rising; having large cakes of floating sewage mud. This mud was held at the surface by the gas being generated in it. A large percentage of the docks along the river were falling into the stream. The river was littered up with old worn out bridge protections which interfered with the passage of boats, and in fact often proved a menace to the boats, for the reason that the piles were rotted off below the surface of the water. Not only the appearance of the river was objectionable to the eye but the odors coming from it were objectionable to the nostrils; and at times of flood could be smelled for long distances. It was a disgrace to a civilized community at that time.

Q. Which way did the river flow? Did it have any current?

A. At times it flowed in different directions. The current was practically stagnant except in times of floods due to heavy

rains, and the run-off of melting snows. Although the Bridgeport Pumping Works were operating, pumping between forty and 50,000 cubic feet of water per minute out of the South Branch, this was so insufficient that it did not make any perceptible current; and often the current could be observed running towards the lake, due to the sudden drop of the lake level.

When the lake would rise, one might observe a current of water coming in from the lake, but generally the river was stagnant.

In times of heavy rains, this sewage polluted water was driven by the storm run-off into the lake, polluting the water supply. This was traced to several miles from shore, and went even beyond the present location of the Four Mile Crib.

On account of the lake rising and falling as stated above, large quantities of this sewage polluted water found its way into the lake and resulted in not only the river itself being objectionable to the eye and nose, but the lake at the mouth of the river was objectionable. It contained large quantities of sewage pollution for a considerable distance from the mouth of the river.

Q. Was there any change brought about after the opening of the Drainage Channel, in this condition which you have described?

A. It has absolutely remedied this condition, so that at the present time there is no local nuisance in the Chicago River and the sewage does not get into the lake polluting the water supply at any place between the Calumet River and the south line of Evanston.

Q. Do you know what has been the cost of the works built by the Sanitary District of Chicago and the City of Chicago, for the purposes of sanitation up to December 31, 1912, that you have described?

A. I do. Up to December 31, 1912, an amount of $61,-845,838 had been expended by the Sanitary District of Chicago and the City of Chicago for the construction of works now in operation. The works of the Sanitary District of Chicago include the Main Channel, North Shore Channel, and the various appurtenances necessitated, including bridges, the enlargement of the Chicago River, the diversion of the Des Plaines River, and the construction of flushing pumps. Those paid for by the City of Chicago include the intercepting sewers on the North and South Sides, the Lawrence avenue sewage pumping station, and also the sewage pumping station at

Fullerton avenue and 39th street. The Sanitary District, as stated before, paid part of the construction of the 39th street station.

Q. Did you state the capacity of the 39th street pumping station and conduit, in taking water away from Lake Michigan?

A. No, I did not. It has a capacity of 2,000 cubic feet per second, or 120,000 cubic feet per minute.

The Lawrence avenue pumping station has a capacity of 40,000 cubic feet per minute.

Q. What is the cost of the works that you have described, built by the Sanitary District and the City of Chicago for the purposes of sanitation for a diversion of approximately 10,000 cubic feet of water per second through the main channel, at a velocity of 1¼ miles per hour or less through the Chicago River?

A. It is the intention to flow 8,000 cubic feet per second through the main river and the south branch to its junction with the South Fork of the South Branch, at which place will come an additional 2,000 feet from the 39th street pumping station, and from this junction of these two branches to the Main Channel, a flow of 10,000 cubic feet.

As stated before, this stretch of the river is wider than the river is east and north of Ashland avenue, and is fully capable of taking the 10,000 feet without creating a velocity of probably over a mile an hour.

The cost of the works built and paid for by the Sanitary District of Chicago and the City of Chicago, for the purposes of sanitation, with a rated capacity of 10,000 cubic feet per second through the Main Channel, and having a velocity in the Chicago River not to exceed a mile and a quarter per hour is $64,095,000.

This cost is made up of the amount expended by the Sanitary District on completed works, which has already been mentioned, and the expenditure by the City of Chicago for works which I have already described, and for the work which has been practically finished during the last year, which is the widening of the eastern end of the present Main Channel, which I have spoken of before as being capable of progressive development; and also includes an estimate of the cost of completing the Chicago River widening to 200 feet. There yet remains four places where it is not quite completed; and certain other minor details, which go to bring this figure up to the amount stated.

These costs have been taken from the books of the District and the City of Chicago. An allowance has been made for the actual interest on the bonds prior to the opening of the Main Channel in 1900, an estimated amount for interest during construction for works built by the District after 1900, and a proportion of the overhead charges of the District pro rated in accordance with the construction and maintenance expenditures. An allowance has also been made for the interest during construction on the city expenditures.

I would in this connection submit a table which gives in some detail the money that has been expended for different purposes and projects.

COST OF WORKS OF THE SANITARY DISTRICT OF CHICAGO AND THE CITY OF CHICAGO.

The Sanitary District of Chicago— To December 31, 1912.	
Right of Way,..................	$9,703,018.37
Construction of Main Channel and Controlling Works,.......	19,813,197.96
Bridges (Incl. Chicago R., North Branch and North Shore)	6,633,073.23
North Shore Channel and Wilmette P. Sta.................	1,450,985.83
Rivers (Chicago River, River Diversion, and North Branch)	3,666,720.23
Flushing and sewers,............	782,150.20
Joliet (Joliet Project, incl. bridges)	1,601,104.30
Administration, Engineering, Legal and Clerical Expenses (Excluding water power eng, and Calumet Sag and prorated M. & O. charge)........	6,658,923.05
Miscellaneous (Illinois and Michigan Canal)	167,404.88
Bond interest and Premium Acct. to Dec. 31, 1899, actual,..	2,950,618.42
Interest computed on construction carried on from Jan. 1, 1900, to Dec. 31, 1912, allowing equivalent one year at 4¼ per cent., ...	737,697.42

Damages, Lands, Marine, personal, ...	276,782.11	$54,441,676.00
Contract Work in 1913 and 1914.		
Estimated Overhead Expense,...	900,000.00	
Estimated Cost of Dredging,....	1,486,085.00	
Interest during construction 1 year at 4¼%,.................	63,158.61	$ 2,249,243.61
		(Exhibit Cont.)
	For	$56,690,919.61
The City of Chicago—		
Intercepting Sewers, Land, etc.,.	$5,312,024.74	
Fullerton Ave. Pumping Station,	115,308.75	
Lawrence Ave. Pumping Station,,	452,635.65	
39th Street Pumping Station,...	944,143.98	
Estimated Interest during Construction—half period on four year basis...............	580,049.62	$ 7,404,162.74
		$64,095,082.35

Q. What do you estimate the annual and capitalized cost of the works for the diversion of 10,000 cubic feet per second?

A. The annual cost of the works for a diversion of 10,000 cubic feet per second is $508,832.09, including maintenance and operation, overhead charges and depreciation; and an allowance has been made for the receipts from rental.

This brings the total cost of a 10,000 cubic feet diversion project up to $76,067,582. This sum includes the annual cost capitalized at 4¼ per cent., and the original construction investment. The details are as follows:

M. & O. acct. 8,000 c. f. p. s.	$210,036.99
Estimated overhead,	50,032.33
Depreciation:	
Main Channel, etc., as of 8,000 c. f. p. s.	265,030.68
Addit. investment	
½ of 1% on $2,249,243.61	11,246.22
City Acct.	
½ of 1% on 6,414,440.88	32,072.20
5% on 409,672.24	20,483.61
	$588,902.03
Less rentals,	80,069.94
Annual,	508,832.09
Capitalized at 4¼%,	11,972,500.00
Investment,	64,095,082.00
Corrected figures,	$76,067,582.00

Q. In these estimates of cost, have you made any allowance for the expenditures on the Calumet-Sag channel?

A. No.

Q. What amount has been expended up to the present time on account of the Calumet-Sag Channel work, including engineering, but exclusive of overhead charges?

A. To December 31, 1913, about $2,080,000, has been expended on the Calumet-Sag Channel. This includes the construction of the channel, purchase of right-of-way, engineering, legal and real estate expenses; but no allowance for overhead or interest upon the money invested. The additional liability incurred on account of contracts that have been awarded is about $3,300,000. This brings the total amount of the liabilities up to about $5,380,000.

Q. What do you estimate the cost of the Calumet-Sag Channel, for a diversion of say 2,000 cubic feet per second?

A. The estimated cost of the completed project is $14,290,000. This is made up of the items as given in the following table. This includes the construction of the channel for a capacity of 2,000 cubic feet per second, with controlling works, intercepting sewers to bring the sewage to the channel from the principal centers and for the sterilization of certain storm overflows, land, engineering and contingencies.

CALUMET SAG CHANNEL

2000 C. F. P. S.

Canal Proper, incl. Eng. & Con.		$8,140,435.00
Contingencies 10%,		814,043.00
Interest during Constr.—		
Allow for three years at 4¼% on, $8,954,478,		1,141,695.00
Old Accounts—		
Main Channel Extension,	$458,082.50	
Bridges,	179.08	
Engineering Expense,	32,969.69	491,231.27
Interest on $491,231.27 1 year at 4¼%		20,877.33
		$10,608,282.53
Intercepting Sewer (1930) at 900 gals. P. Cap,	$1,468,045.00	
Pumping Stations (Bldgs. 1930 Eq. 1920,	617,025.00	
Disinfection Plants,	489,054.00	
Sewers account West Hammond, Harvey and Hegewisch,	177,214.00	
Land,	100,850.00	
	$2,852,188.00	
Eng. & Conting. 15%	427,828.00	
	$3,280,016.00	
Inter. during Constr.—		
Allow 3 years at 4¼%	401,802.00	3,681,818.00
Total cost,		$14,290,100.53
Capitalized operating cost of Channel, etc,		1,424,500.00
Capitalized operating cost sewers, etc., as of 1920,		3,734,870.00
Total, Capitalized and Construction,		$19,449,470.00

Q. What is the capitalized operating cost of the Calumet-Sag Project?

A. The capitalized operating cost of the channel is $1,424,500, and of the sewers that are to be constructed in connection with it $3,734,870, bringing the total capitalized cost and construction cost up to $19,450,000 in round numbers.

Q. You spoke awhile ago about the channel as designed for an enlargement to capacity of at least 4,000 cubic feet of

water per second. What will be the cost to bring it up to that figure?

A. The construction cost of the Calumet-Sag Project for a diversion of 4,000 cubic feet per second is estimated to bring the total construction cost of this channel when enlarged to 4,000 cubic feet per second up to $19,925,000. The capitalized operating cost would be, $6,229,000. The total capitalized cost and construction cost will be $25,729,000, in round numbers. The following is an estimate in detail, giving these figures:

CALUMET-SAG CHANNEL.

4000 C. F. P. S.

Cost of 2000 C. F. P. S. project,		$14,290,100.00
Additional to widen channel,		5,000,000.00
Interest during Constr., say 2 years at 4¼% ($200,000) (12,500)		425,000.00
Additional to bring equipment Pump Sta., etc., up to 1930.		
Pumping Sta.	$ 75,000.00	
Miscellaneous sewers, etc.	135,000.00	210,000.00
Total Construction Cost,		19,925,100.00
Capitalized Operating Cost (as of 1930)		
Total for sewer,		4,216,800.00
Total for channel,		2,012,740.00
Total Capitalized and Construction cost,		$25,729,640.00

Q. Did you state the capacity of the Main Channel from the terminus of this Calumet-Sag Channel to the controlling works?

A. That is 14,000 cubic feet per second.

Q. What are the summarized construction costs and capitalized costs, gross, for the works required to dispose of the sewage within the boundaries of the Sanitary District, on a dilution basis, for diversions of various amounts, 10,000-12,000 and 14,000 cubic feet per second?

A. The following is a table giving these costs for the different flows asked for in the question:

Flow Cu. Ft. Per Sec.	Investment of of Construction cost	Annual Cost Operating Plus Depreciation.	Capitalized Gross Cost.
10,000	$64,095,082.00	$508,832.00	$76,067,600.00
+2,000	+14,290,100.00	+219,273.00	+19,449,470.00
12,000	78,385,182.00	728,105.00	95,517,070.00
+2,000	+5,635,000.00	+58,133.00	+7,002,840.00
14,000	84,020,182.00	786,238.00	102,519,910.00

Q. What is the cost of the electrical development of the Sanitary District?

A. The cost to December 31, 1912, was $5,349,241.57. This comprises the book account valuation of the electrical development of $5,047,625.57, plus an allowance made to have this cost comparable with the other costs for the purpose of our analysis, the allowance covering interest during construction, taken at 4¼% on the cost during construction for ½ the period during which these works were being built.

Q. What are the summarized construction costs for the works required to dispose of the sewage of the inhabitants of the Sanitary District for the diversion of various amounts, say 10,000—12,000 and 14,000 cubic feet per second, on a net basis, making allowance for any income from the hydro-electric power works?

A. I have prepared a table, which is given below, giving these costs. It gives the investment cost on the construction, the annual cost of operation and the gross capitalized and construction cost and the capitalized electrical credit; and this is subtracted in the last column from the gross capitalized cost. The allowance for the income coming from the electrical department are based on the value in the Chicago market for electric energy used for commercial purposes; and is based on what could be developed over that which could be developed with a flow of 4,167 cubic feet per second.

The present electrical plant and equipment is sufficient to generate the energy coming from the flow of 14,000 cubic feet per second, with the possible exception that one electrical and water wheel unit would have to be installed, provision for which has been made.

NET CAPITALIZED COST DILUTION SCHEME.

Flow Cu. Ft. per Sec.	Investment or Construction	Annual Cost Operating Plus Depreciation	Capitalized Gross Cost	Electrical Credit Capitalized	Net Capitalized
10,000	$64,095,082.00	$508,852.00	$76,067,600.00	$13,242,000	$62,825,600
12,000	78,385,182.00	728,105.00	95,517,070.00	17,790,000	77,720,070
14,000	84,020,182.00	786,238.00	102,519,910.00	22,306,000	80,213,900

Q. Will you state the cost of the works built inside the limits of the Sanitary District of Chicago for supplying water to the people inside the corporate limits of the Sanitary District of Chicago? Will you also state the cost within the same corporate limits for the collection of sewage? Summing these up with the amount expended by the Sanitary District for the removal of sewage, also state what is the total expended for the entire scheme for supplying water and collection of sewage and the removal of sewage to date?

A. Since the sewerage system was started to be installed in 1855, the City of Chicago has expended, up to December 31, 1912, $31,867,268.68. This is exclusive of any intercepting sewers. The sewer systems in the outlying villages and towns up to an average period of 1911, had cost $5,246,764.16.

The water supply system of the City of Chicago up to December 31, 1912, had cost $49,948,318.06. The water supply system of the outlying villages and towns within the Sanitary District, so far as the same can be obtained, has cost about $2,000,000 for five towns out of seventeen outside of Chicago, but inside the Sanitary District. No allowance is made for interest during construction in these figures. Adding the expenditures of the Sanitary District as given above, brings the total amount expended for water supply and sewage disposal up to the total sum of $150,908,189.64. If all charges could be obtained and the methods of work known, this figure would be materially increased.

Q. Now, you have described the various works of the Sanitary District. What is the general purpose, exclusive of the electrical development?

A. The purpose of the works of the Sanitary District of Chicago is to provide for the proper and efficient sewage disposal, and to protect the water supply from pollution; and in so doing to so dilute the sewage that local nuisances will be prevented within the corporate limits of the Sanitary District; and to dilute this sewage with a minimum flow of 3⅓ cubic feet per second for every 1,000 people sewering into the channels of the District, so that nuisances will be prevented

in the Des Plaines and Illinois Rivers below the end of the works of the Sanitary District.

Recess to 2:15 P. M.

After Recess 2:15 P. M.

GEORGE M. WISNER, resumed the stand and testified further as follows:

Mr. Adcock: Q. Mr. Witness, do you consider this minimum legal ratio of dilution, which you referred to in your last answer, adequate for the conditions in the Sanitary District of Chicago?

A. For the disposal of the domestic sewage, I consider that 3⅓ cubic feet per second per thousand people draining into the channel is sufficient.

Q. What is the effect of the main channel upon the Chicago River, the Des Plaines River from Joliet to the Illinois River, and on the Illinois River?

A. The effect of the flow through the Main Channel is to dilute the sewage coming from the Sanitary District to such an extent that it avoids all local nuisances in the Main Channel itself, and in the Des Plaines and Illinois Rivers. It flushes out the Chicago River, and the Des Plaines River from Joliet to the Illinois River is thoroughly flushed under summer conditions; whereas, formerly there was practically no flow in the Des Plaines River north of the junction of the Kankakee and the Des Plaines. This continued for many months in the year.

In the Illinois River, the effect has been to produce a constant flow, and it has improved the conditions of the water of the Illinois River all the way to the Mississippi River, over what it was under summer conditions.

The effect has also been to improve the navigation in the Des Plaines and the Illinois Rivers, by increasing the dry weather flow and giving greater depths. This also, as stated, has improved the sanitary conditions, by affording increased dilution for the cities and towns sewering into the river below Chicago.

The value of the water powers on the Illinois River has also been increased, by increasing the flow.

The value of the fish and mussel industry in the Illinois River has materially increased since the opening of the Main Channel. In my opinion this improvement is almost wholly

due to the maintenance of a cleaner condition of the river, and the additional food furnished by the products of the self-purification of the stream for supporting fish life.

Q. What has been the improvement in the Illinois River, with reference to the preservation of fish life, since the opening of the Drainage Canal?

A. The fishing industry has gradually increased in value. The figures given in the special report of the United States census for 1908, on the Fisheries of the United States show that the fisheries in the Illinois River have grown as follows:

Year.	Tons.	Value.
1894	3,000	$162,000
1899	7,000	382,000
1908	23,000	860,000

Besides the growth of the fishing industry, there has been a great increase in the mussel industry. The mussel shells are used for making buttons. This is shown by the following table, taken from the special report of the United States census, 1908:

Year.	Tons.	Value.
1894	24	$ 700
1899	2,500	43,000
1908	20,000	184,000

And in that time there was also $170,000 worth of pearls taken from these mussels. From the investigations of the Sanitary District, it appears probable that the amount of fish now caught exceeds the figure given by the census of 1908.

Q. Will you describe briefly the conditions in the Chicago and Illinois Rivers prior to the opening of the Chicago Drainage Canal?

A. I have described the conditions in the Chicago River prior to the opening of the canal in the former answer. The Illinois River was a slow, sluggish stream in the summer time, having a very small discharge, and in times of run-off of melting snows and heavy rains, the discharge was quite voluminous. The condition of the river was that it was a polluted stream, particularly below Peoria where the sewage from Peoria and the wastes coming from the distilleries polluted the water to such an extent that it was practically a nuisance. From a navigation standpoint there was some little navigation maintained by dams, which produced slack water, and it was generally navigable from Utica to the Mississippi.

I would say in this connection about the condition of the Illinois River, that we have since 1909 made regular examinations, both chemical and bacteriological of the waters of the Illinois River, showing the effects of the Drainage Canal upon the Des Plaines and the Illinois Rivers, and it shows that the waters are in good shape from the standpoint of the oxygen content below Marseilles. This we have carried on continuously for the last several years.

Q. You mean this investigation?

A. This investigation.

Q. Will you briefly describe the present condition of the Main Channel from the standpoint of odors and the location of deposit?

A. We have carried on the same investigations in the Main Channel, in regard to the condition of the combined sewage and fresh water, by having the water analyzed regularly. Up to the present time pretty nearly all of the manufacturing wastes from the city have been going into the sewage and channel without any preliminary treatment. There has been some slight treatment by means of removing part of the settling solids from certain industries. The result has been that there has been large accumulations of deposits in certain parts of the channel, where at times in the hot weather local nuisance is present; but the condition is now so much better than it was prior to the opening of the canal, which parallels the old Illinois and Michigan Canal, which prior to 1900 ran its capacity full of septic sewage, water and mud, so that the improvement down the Des Plaines Valley has been considerable, but at the same time there has not been sufficient water to take care of and properly oxidize both the domestic sewage and the manufacturing wastes, coming from the large industries in this city. There are large deposits of sewage mud in the Main Channel from the end of the narrow earth section that I have spoken of to Willow Springs where the rock section starts. There is practically no sludge deposits in the rock section until Lockport is reached, where the Main Channel was widened out for the purpose of making a basin at the controlling works, and in the stretch of the new channel built for the development of water power. In these stretches of the channel, there have been big deposits which in the summer time produce gas and are in a fair way to make a local nuisance. In the vicinity of the controlling works, odors are at times perceptible. This is where the deposits occur principally.

Q. Can you state what the population of the District has been since 1900, up to and including the present time?

A. Yes.

Q. Will you state what the average flows have been in the Main Channel, with reference to the minimum ratio provided by law?

A. In the last few years, it has been practically what is called for by the law, but prior to that it was not up to what was called for by the State law, for the reason that the Chicago River had not been improved and the District was restrained by the Secretary of War from causing a current in the South Branch of the River to exceed a mile and a quarter an hour. For that reason, the flow in the early years of the canal was not what it should have been or what was called for by the state law; that is 20,000 cubic feet per minute for every 100,000 people draining into the channel.

Q. Have you prepared a tabulation showing the population within the limits from year to year between 1900 and 1913, and the average daily flow in cubic feet per second based on the population as provided by the state law?

A. Yes, sir.

Q. Will you kindly give that to the Commissioner?

A. The following is the table:

Year	Population Based on U. S. Census		Average Daily Flow in Cu. Ft. per Second Population Basis	
	Within Corporate Limits S. D. C.	Actually Tributary M. C.	Total	Actual
Original Limits				
1900..............	1,638,656	1,294,312	5462	4314
1901..............	1,690,874	1,331,119	5636	4437
1902..............	1,740,129	1,364,961	5800	4569
1903..............	1,789,593	1,399,014	5965	4663
Territory Annexed				
1903..............	1,933,694	1,543,115	6445	5144
1904..............	1,987,205	1,581,376	6624	5271
1905..............	2,040,717	1,614,228	6802	5381
1906..............	2,094,223	1,887,605	6981	6292
1907..............	2,147,740	1,933,176	7159	6444
1908..............	2,201,250	1,978,744	7337	6596
1909..............	2,254,763	2,091,015	7516	6970
1910..............	2,308,276	2,139,787	7694	7132
1911..............	2,361,788	2,188,524	7873	7295
1912..............	2,415,300	2,237,330	8051	7458
1913..............	2,468,811	2,285,993	8229	7619
Territory Annexed				
1913..............	2,498,660	2,285,993	8329	7619

Q. Mr. Wisner, the flow of the water through the channel, has that been approximately the figures as indicated in the last column of that table?

A. Yes, sir, subsequent to 1908.

Q. Do you have any comments to make upon the tabulations made with reference to the actual flow further than you have stated?

A. Only to this extent, that in the early part of 1908, the water power plant was installed, and the only way of measuring the water that went through the canal was to use the water wheels as a meter. These wheels had been tested in a flume at Holyoke, by which in an approximate way we could get at their discharge under different gate openings.

I have found out, however, recently that these discharges are somewhat small, and through some investigations that we have been making and are making, I think that the flow as indicated in the last column from 1908 on is somewhat small. This is based upon measurements made by myself, and some that have been submitted to me made by the United States Government.

Q. The amounts shown to have been discharged through the Main Channel of the Sanitary District in the last column, does that include lake water, sewage and storm water and everything?

A. It includes everything that passes through the end of the canal at Lockport.

Q. What in your opinion has been the hygienic improvement in the Chicago water supply, if any, due to the opening and operation of the Main Channel and its appurtenances?

A. The improvement was very marked after all the sewage had been diverted from the lake. The intercepting sewers were not wholly completed until 1910, but were practically completed on the south side in 1906 and on the north side in 1908. Since that time, the reduction has been more marked in the typhoid fever death rate, so that today the water supply from the criterion of typhoid fever death rate compares very favorably with other large cities in the United States and in Europe. The typhoid fever death rate is lower than in many cities having filtered water supplies. In 1912, Chicago's typhoid fever death rate was 7.5 per hundred thousand. From 1909 to 1912, the typhoid fever death rate in Chicago was lower than that of Pittsburg, Philadelphia, Washington and New Orleans, all of which have filtered water supplies. The rate was also lower in Chicago than in other

cities having filters; namely, Albany, Atlanta, Birmingham, Columbus, Grand Rapids, Indianapolis, Louisville, New Haven, Oakland, Providence, Scranton and Toledo.

Q. Have you made any study to show the probable population discharging sewage into Lake Michigan subsequent to the opening of the Main Channel, first with reference to the District as a whole, and secondly the city water front immediately adjacent to the intakes?

A. I have made such a study, using the shore line within the present limits of the Sanitary District as a guide, to show the population discharging into Lake Michigan after the opening of the Main Channel. The results are given in the following table. This table shows the total population located in Chicago, the north shore towns and the Calumet district, which drains its sewage into the lake, on January 17, 1900:

After the opening of the Main Channel, January 17, 1900.

POPULATION DISCHARGING INTO LAKE MICHIGAN INSIDE PRESENT SHORE LINES OF THE SANITARY DISTRICT.

Year	Total	Between 87th Street and South Boundary of Evanston
1900	344,344	223,625
1904	405,829	265,940
1905	426,489	281,708‡
1906	206,623	57,100
1907	214,564	60,300
1908	222,506	63,500†
1909	163,748	0
1910	168,489	0
1912	177,970	0

‡39th Street pumping station district diverted in 1905.

†Lawrence Avenue pumping station district diverted in 1908.

Q. And this lesser number from year to year, as indicated upon this table, of population discharging into the lake and within the present shore lines is due to the fact that intercepting sewers were opened from time to time, and the sewage of the population discharged into the Main channel where it is tributary to the Sanitary District, is that correct?

A. Yes, sir. The third column of the table shows the population between 87th street in Chicago on the south and Evanston on the north, that has drained into the lake since the opening of the channel.

Q. And the second column shows the total?

A. The total including Evanston and the Calumet District.

Q. And prior to 1900, all of the sewage substantially was drained into the lake?

A. Substantially, with the exception of what was pumped through the old Illinois and Michigan Canal.

Q. What is the effect of the sewage from the towns in Lake County, Illinois, on the water supply of Chicago?

A. The effect of the sewage from the towns in Lake County, Illinois, is practically nill on the water supply of Chicago. These towns include Highland Park, Lake Forest and Waukegan. There are no currents in Lake Michigan, other than varying drifts produced by the wind. The sewage discharge in Lake County nearest the Lake View crib is over 16 miles away. The population is small, so that the protection to Chicago by dilution and storage and consequent death of pathogenic bacteria probably suffices for many years to come. The danger is to the water supply of the villages themselves more than to the City of Chicago proper.

Q. What is the effect of the sewage from the towns in Lake County, Indiana, on the water supply of Chicago?

A. The effect of the sewage from the towns in Lake County, Indiana, on the water supply of Chicago, as taken from the 68th Street or the Dunne cribs is largely influenced by the condition of the Calumet River, into which these towns discharge a part of their sewage. Flood discharges will heavily pollute the water of the lake around the crib. In drier weather, pollution may occur with sudden rains. The pollution has been traced eight to ten miles into the lake.

The district is taking steps now to reverse the Calumet River and to keep the sewage coming from the Sanitary District out of it, so that in times of flood the water in the river will not be polluted with sewage. It is also negotiating with the Indiana towns to get them to remove or purify their sewage before it enters the lake or the Calumet River, to such an extent that it will be non-putrescible.

Q. Have you made an examination at or about the present time with reference to the quality of the Chicago water supply?

A. Yes, sir.

Q. What is it?

A. The typhoid fever death rate shows that the quality of the Chicago water supply is excellent from a hygienic standpoint, and is far purer than most of the larger municipal supplies in the United States.

The 68th Street and Dunne cribs on the south, and the

Lake View crib on the north are, however, exposed to possible pollution.

Q. That is in the manner you have just mentioned, is it not?

A. Yes, sir, and on the north on account of Evanston not having diverted its sewage as yet. The effect on the Chicago water of outside pollution from the north of the Cook County line is very remote. Pollution from the Calumet region in Indiana is very intermittent, but may be severe in its effect on the 68th Street and Dunne cribs.

The effect of pollution coming from passenger vessels and other vessels is being minimized by the action of the city in keeping the vessels away from the intakes, and to have the closets locked, or tanks to store the sewage in while the vessels are passing in and out of the harbor. The shipping factor is particularly of moment in the summer months. This chiefly affects the cribs at the mouth of the Chicago River.

In the recent storms, this fall, the water supply of the city has been extremely turbid at times and in consequence the newspapers have quoted the Health Department as advising the boiling of the water. The condition of the water and the attitude of the Health Department was investigated by the Engineering Department. The records of the analysis made by the Health Department laboratory shows practically no difference in the hygienic quality of the water on account of the storms. The turbidity or aesthetic appearance of the water was, however, unsatisfactory. The Health Commissioner, Doctor Young, and his labortory director, Doctor Tonney, both admitted advising the boiling of the water in an informal way to the newspaper men, but stated that this was a precautionary measure only, inasmuch as it is impossible to learn the quality of the water by immediate tests. The bacteriological tests employed do not give results until after 48 hours have elapsed. Their opinion was the same as ours, that only the appearance of the water had been injured by recent storms, and that the hygienic quality of the water was unimpaired, rendering boiling unnecessary.

Q. What has been the improvement, if any, in the typhoid fever death rate in the City of Chicago since the opening of the Drainage Canal, and please also state the reduction of the death rate from diarrhoeal diseases; and whether this reduction in typhoid fever death rate has been as great as the same has been in other cities of the United States, during the same period of time?

Mr. Hopkins: I think the witness ought to be required to state the basis of all this testimony, because he cannot know all that he has testified to here, and we would like to have the source of it.

Mr. Adcock. Q. State the source. The death rate from typhoid fever and diarrhoeal diseases that you have referred to and the conditions pertaining to same are from what statistics?

A. From the records of the Health Department of the City of Chicago.

Q. They were produced upon a previous hearing?

A. That is my recollection.

For 13 years prior to the opening of the Drainage Canal, the average typhoid fever death rate was 52.6 per one hundred thousand. For the 13 years after the opening of the canal, the death rate was 19.9 per one hundred thousand. This reduction is about 68 per cent., and would have been more marked had the sewage been intercepted completely earlier in this period.

Q. That is in the last 13 years?

A. In the last 13 years. The average death rate for the diarrhoeal diseases for the period before the opening of the drainage Canal was 418.2 per one hundred thousand. This was reduced to 187.2, a reduction of 55 per cent.

The typhoid fever death rate in Chicago has been reduced markedly, even compared with the reductions affected in cities where filtration plants have been installed. The rates for 1911 and 1912 were lower than the rates in the cities of Philadelphia, Washington, Pittsburg, and New Orleans, where filtered water is supplied. They are as low as in Boston and lower than San Francisco where the water sheds are carefully watched and pollution is kept out of the reservoirs.

Q. What is the present cost of typhoid fever to this community, and what are the costs which the community would have been called on to bear if the typhoid fever death rates prior to the opening of the Drainage Canal had been maintained.

Mr. Hopkins: Objected to as not within the witness' knowledge and no reliable statistics are obtainable; and it is impossible of determination.

A. This is best shown by Wisner Exhibit 3, January 20th, 1914, on which the various costs to the community are indicated. These costs are made up on the assumption that a life is worth $10,000 as fixed by certain statutes in Illinois, and

with allowances for the cost of nursing, medical attendance, drugs, loss of wages, and funeral expenses in the case of death. The ratio of deaths to cases has been taken at ten per cent.; that is for every death reported there has been assumed at least ten cases. Two curves are plotted for the probable costs if the channel had not been built, one figured on the average rate of typhoid fever deaths for the 13 years prior to the opening of the canal, and other figured on the average of the four worst years from 1890 to 1893 inclusive.

(Chart identified by witness was marked Wisner Exhibit 3, January 20th, 1914.)

Q. The chart which you have referred to and which has been marked Wisner Exhibit 3, that has been made up under your direction, upon the premises which you have just stated?

A. Yes, sir.

Mr. Adcock: It is offered in evidence.

Objected to by counsel for the complainant.

Q. Has the same improvement in typhoid fever death rates been observed in the Calumet region of Indiana, adjoining the Sanitary District of Chicago?

A. No, sir.

Q. Have other cities of size around Lake Michigan shown improvement in their typhoid fever death rate during the last 12 years, as compared with the previous 20 years? Has the improvement in any degree been comparable to that in Chicago?

A. No. In Milwaukee, for instance, the typhoid situation has been practically unchanged for over 30 years, the rate at times being practically as high as 30 years ago. The improvement in Chicago has been very favorable. In Michigan City, a city of 19,000 people in 1910, the typhoid rate has been high, with violent fluctuations, extending over a range of from nothing to 112 deaths per one hundred thousand between 1882 and 1907.

Q. From what source did you get the information?

A. From the reports of Boards of Health and Health Commissioners of the different cities, and published statistics of the United States census, and every available source; some of it from government reports made in the geological survey.

Supplementing my answer to a previous question, I desire to state: The same improvement in typhoid fever death rates in the towns in Indiana, adjoining Illinois, has not been ob-

served. The current typhoid fever death rates are shown on Wisner Exhibit 4, January 20, 1914.

These are for the towns of Hammond, Whiting, East Chicago and Gary, Indiana. Whiting and East Chicago discharge their sewage directly into the lake in the neighborhood of their water supplies, and Hammond and Gary discharge their sewage into the Calumet River, thereby affecting at times their own water supply and that of the City of Chicago taken from the 68th Street Cribs. The conditions in Indiana adjoining the Sanitary District are very unsatisfactory.

Referring to Exhibit Wisner Number 4, you will notice that for Whiting in 1908, they had a death rate of 140 per one hundred thousand, where Chicago had a death rate of about 16 or 17. The effect of keeping the sewage out of the water supply of Chicago is shown very markedly by this exhibit, in that since 1904 there has been no marked epidemic of typhoid, whereas all of these other three towns lying adjacent to Chicago and having practically the same milk supply, same foods, and generally the population being of the same general character as that of Chicago, have had several epidemics as shown by the peaks on these so-called curves, which give the death rates per one hundred thousand of the people living in these towns.

Q. The line on that chart shows that Chicago has had no epidemics, and is gradually going down?

A. Since 1902, Chicago has had nothing that represents an epidemic, and the line from 1904, the solid line on this exhibit, which represents the death rate from typhoid fever in Chicago, has been gradually going down, showing a decrease in the typhoid fever death rate.

(Chart produced and identified by the witness was marked Wisner Exhibit 4, January 20, 1914.)

Q. Assuming that 4,167 cubic feet per second is allowed as the diversion from the lake through the channel, what would be the effect on the water supply and sewage disposal facilities of the District?

A. The effect of a diversion of only 4,167 cubic feet per second would injure the quality of the water supply and seriously disturb the sanitary conditions in the Chicago River, the Desplaines and Illinois Rivers; and the water supply would be subjected to pollution, since the reversal of the flow of the Chicago River could not be prevented. This might occur on periods equivalent to six to 10 days per year.

The immediate effect on the canal would be to cause the line of no oxygen to come close to the city. By that I mean that all of the oxygen in the diluting water would be used up probably before the combined sewage and water got into the canal. Anaerobic conditions would prevail at Lockport, and a nuisance would result in the Desplaines River at Joliet which would be serious. Sludge banks would form along the whole length of the channel. This would increase the odors and cause a nuisance.

The Illinois River would also be affected, since the dilution would not be sufficient to balance half of the oxygen requirements. This would tend to spread anaerobic conditions down the river, and would interfere with the fishing industry, ending fish life until down as far as south of Peoria. Nuisance would occur at Morris, Marseilles, Ottawa, and Peru, and possibly Chillicothe, and there might be nuisances below Peoria.

In my opinion, it would be impossible to construct remedial works of problematical efficiency in less than ten years. If the flow were limited at any time before the completion of these works to 4,167 cubic feet per second, with a constantly increasing population, intolerable conditions would arise in the canal, the Desplaines River, through Joliet and in the Illionis. Conditions in large portions of the Chicago River proper would be a living nusiance.

Q. Sludge would accumulate in the Chicago River?

A. Yes, sir.

Q. What would happen to this in times of high water when the river were reversed as you just mentioned?

A. Then this accumulation of sludge would probably be scoured into the lake, polluting the water supply.

Q. Along with the sewage?

A. With the sewage polluted water of the river itself.

Q. Assuming that the flow is reduced at once to 4,167 cubic feet per second, do you know of any emergency treatment to tide over the nuisances which would accrue until the remedial works described by you could be constructed?

A. I know of no thoroughly satisfactory emergency treatment. If the flow were continued in accordance with the minimum ratio of 3⅓ cubic feet per second, a double expense would be thrust upon the Sanitary District, as it would have to develop the canal to a capacity of 12,000 cubic feet per second before the other works could be put into service.

The only suggestion would be the use of an excessive amount

of chloride of lime. This would be unsatisfactory, as the sludge would still go into the river and create nuisance, and in addition would be very costly. Time would be required to install emergency works on such a large scale.

Q. Have you made any estimate with reference to the floating population of the City of Chicago, or is there one that you have in mind?

A. Yes, sir; I have had one made. I estimate that the daily floating population by 1920 in Chicago will be 300,000 people. I have found that there is to-day a transient population of 68,000,000 in the course of a year, including through and local travellers from outside the boundaries of the district, who may be assumed to come in contact with conditions in the City of Chicago.

Q. From what sources did you obtain the figures upon which the estimate is made?

A. I am of the opinion that the estimate is small, if anything. I got all the records obtainable from the different railroads coming into Chicago and complied these figures from figures given to us; and also from steamship companies. I had the people counted coming into the stations for a certain length of time to get an estimate of the number of people where the railroad companies had no sufficient data at hand.

Q. Have you computed the probable population of the Sanitary District in the years 1920, 1930 and 1940?

A. I have. This is based on the United States census reports, and upon the probable growth of the city in the future as based upon what it and other large communities have done in the past.

Q. Have you computed the amounts of water required for the population based upon the minimum legal flow for dilution?

A. Yes, sir; I have.

Q. Will you state what that is; and also your compilation with reference to future population?

A. It is as follows:

Year	Population	Flow required in Cu. Ft. per second
1910 Actual	2,308,276	7694
1920	3,110,036	10367
1930	3,866,023	12887
1940	4,466,000	14900

Q. What are the available methods in your opinion for

sewage disposal open to cities of large size, according to modern practice?

A. The available methods for the sewage disposal of large cities comprise dilution, screening of the sewage, sedimentation, which is the removal of the settling suspended matter by settling in various types of tanks, chemical precipitation, broad irrigation or land irrigation, intermittent filtration, contact beds and sprinkling filters. These methods may be used in combination, according to local circumstances or conditions. Sterilization by the use of chloride of lime, or liquid chlorine, may also be used on raw sewage and effluents of treatment works.

Screening is useful principally to remove coarse floating material. Sedimentation may remove most of the settling suspended matter, and improve the stability of the liquid from 15 to 25 per cent. Chemical precipitation will remove somewhat more of the settling suspended matter and some of the colloidal matter. In order to make a stable effluent after the suspended matter has been removed, treatment to oxidize the organic matter is required. This is frequently carried out in bacteria beds or biologic filters. Such broad processes include broad irrigation, intermittent filtration, contact beds and sprinkling filters. These methods, however, are not all equally practicable.

The methods of broad or land irrigation and intermittent filtration require very large areas of land. In the United States, broad irrigation is practically abandoned, save in the arid regions, where it is of value principally for the water rather than for any other purpose. Intermittent filtration is not now installed for large cities, but is considered practicable for small towns under 10,000 population, where sand is cheap and land valuable. Sprinkling filters and contact beds are more practical for large cities as a larger population can be taken care of on smaller areas. Of these two, the sprinkling filter is most economical and efficient, as a rule.

Q. Of these methods, which do you consider best adapted to the conditions existing in the territory comprising the Sanitary District of Chicago, taking into account the protection of the water supply, disposal of sewage, and the removal of local conditions of nuisance?

A. The dilution method, by the use of the main channel and a supply of water from Lake Michigan, is the most economical and efficient, the surest and the most effective, in that it diverts all the sewage from the water supply, and works automatically; is not dependent upon any individual

or individuals for its efficiency; and permits of self-purification of the sewage in the ordinary and natural way.

Q. What methods are available, other than dilution, for handling the sewage of the Sanitary District in case the flow required by the legal ratio is restricted?

A. Settling would be the first step to bring about the removal of settling suspended matter. This could be followed by the use of sprinkling filters to produce a stable effluent, as required. Secondary settling basins would probably have to be used to remove the humus formed in the sprinkling filters. Sterilization by chloride of lime or liquid chlorine might be utilized on storm flows and sewage effluents as required by circumstances.

Q. From your studies and observations of the local situation and the estimates presented in this suit, what allowance have you made for the industrial load, that is for the effect of industrial wastes upon the oxidizing capacity of the canal?

A. No allowance has been made for the industrial load, as it is recognized that whatever happens the industrial sewage would have to be cared for in any case. This means that the cost of handling the industrial sewage would be additional to all of the comparative estimates submitted, in this testimony. This has been recognized by the Board of Trustees, and special studies are now being conducted by the engineering department of the District to determine the methods of treatment for the industrial wastes, principally for those of Packingtown and the Stock Yards, and for the tanneries.

Q. Briefly, what is the average dry weather flow as shown by the gagings of the Sanitary District from typical sewage?

A. The dry weather sewage flows vary from 170 to 600 gallons per capita. An average flow of 300 gallons, about, per capita, has been estimated from a study of the flows actually found on various typical areas by gagings made by the Sanitary District of Chicago. The storm flows vary considerably. Maximum storm flows have been found from 50 to 70 cubic feet per second per square mile on areas of some size, with a maximum of 128 cubic feet per second per square mile on small well built areas. Intercepting sewers planned for a flow equivalent to 900 gallons per capita daily are required to care for the first rush of storm flows, and the minor storms.

Q. Assuming that 4,167 cubic feet per second of water are available from Lake Michigan for dilution, what will be the

cost to the Sanitary District for handling population equivalent to diverted flows amounting to 10,000—12,000 and 14,000 cubic feet per second?

A. The costs to the Sanitary District for these additional works are given in the following table:

COST OF CONSTRUCTION FOR SEWAGE TREATMENT ON ASSUMED DIVERSION OF 4167 C. F. P. S.

Items		Equivalent to Diversion of 10,000 c. f. p. s.
Population Distribution Treatment		Net Load in Population.
Lawrence Ave,		997,000
West Side,		0
39th Street,		944,000
Calumet,		207,085
Dilution	1,562,500	
Less Floating,	300,000	
	1,262,000	
Less Factor Safety,	362,000	
Net	900,000	900,000
		3,048,085

Costs	
Lawrence Ave,	$17,595,582.00
West Side,	7,170,045.00
39th Street,	17,549,206.00
Calumet,	5,106,957.00
Storm Water Disinfection,	1,545,988.00
Domestic Sewage Disinfection,	600,000.00
Aeration,	1,065,000.00
North Shore,	1,192,280.00
Public Utilities,	3,453,570.00
Paving,	365,843.00
	$55,644,471.00

Forward, ...	$55,644,471.00
Interest during Construction, 21-1/4%.......	12,500,000.00
Legal and Administration, 10%.............	4,740.000.00
	$72,884,471.00

Population equivalent to a diversion of 12,000 c. f. p. s.,..................................	3,600,000.
Population Equivalent to a diversion of 14,000 c. f. p. s..................................	4,200,000.

Cost Pro-rated from Cost for Equivalent to Diversion of 10,000 C. F. P. S.

Pro-rated for increase of population from 3,000,000 to 3,600,000 equivalent to a diversion of 12,000 c. f. p. s...................	$87,200,000.00
Pro-rated for increase of population 3,600,000 to 4,200,000 equivalent to a diversion of 14,000 c. f. p. s.........................	101,900,000.00

Q. Does this table show the expense to which the District would be put if the supplementary works required with the lessened flow of water are built?

A. Yes, sir, it does. No allowance has been made for the cost of the existing works in this table. The total costs of the projected works on the allowance of 4,167 cubic feet per second, added to the existing works, is given in the following table:

COST OF WORKS FOR SEWAGE DISPOSAL COMBINING COST OF NEW TREATMENT WITH EXISTING INVESTMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Construction Cost of New Works	Construction Cost Existing Works	Total Construction Cost
10,000	$72,884,471	$64,095,082	$136,979,553
12,000	87,200,000	64,095,082	151,295,082
14.000	101,900,000	64,095,082	165,995,082

Q. Have you computed the annual cost for sewage treatment on the same basis and assumption.

A. Yes, sir.

Q. Is that annual cost shown on the table which you now hand the Commissioner?

A. Yes, sir, it is.

The table is as follows:

ANNUAL COSTS FOR SEWAGE TREATMENT ON ASSUMED DIVERSION OF 4167 C. F. P. S.

Item	Basis 10,000 C. F. P. S.
1. General Expenses,	$30,000.00
2. Sewers,	23,000.00
3. Pumping Stations, 4910 W. H. P. at $350	1,820,000.00
4. Sedimentation at $0.15 per capita,	456,000.00
5. Sprinkling filters at 0.10 per capita,	214,800.00
6. Aeration at 0.08 per capita,	171,840.00
7. Disinfection,—	
Storm Sewage,	433,800.00
Domestic Sewage,	370,000.00
	3,519,440.00
8. Depreciation,	1,182,157.00
Total,	$4,701,597.00
9. Pro-rated for increase of population from 3,000,000 to 3,600,000 equivalent to a diversion of 12,000 c. f. p. s.	5,650,000.00
10. Pro-rated for increase of population from 3,600,000 to 4,200,000 equivalent to a diversion of 14,000 c. f. p. s.	6,590,000.00

Q. Do you desire to make any explanation of any of the items included in this last table or any of the other tables?

A. No, sir, I think the table speaks for itself as to what is included.

Q. What does this project or scheme that you have just been referring to provide?

A. This scheme contemplates the construction of intercepting sewers based on a dry weather flow of 300 gallons per capita per day, carrying flows up to 900 gallons per capita per day to Central points for treatment. Above this amount, the storm flows would be discharged into the Chicago River or Calumet River, with sterilization; special tanks being provided to give a contact of 10 minutes on flows based on the maximum peak discharges. Coarse screens and grit chambers are contemplated, with facilities for cleaning. Settling basins are also to be built of the double deck type for dry weather

flow, with capacity up to 900 gallons per capita. Sprinkling filters are estimated for the excess population which cannot be cared for by the extended use of settling tanks. The estimates include the sterilization of all the sprinkling filter and settling tanks effluents before being discharged into the Chicago River or the Canal. The double deck tanks would be designed on a basis of two hours retention of 300 gallons per capita daily in the settling chamber, and six months retention of sludge. The sprinkling filters would be designed on a basis of 12,500 people to the acre, the filters being assumed to be 6 feet 4 inches in depth of filtering stone. Secondary settling tanks are to be used for the filters, nominally of half the size of the primary settling tanks.

Q. What is the basis of the construction estimates given in your last answer?

A. The estimates given are based on the current cost of sewer construction in the City of Chicago, due allowance being made for the probable character of the work, the cost of labor and material, and the character of the excavation to be made. The cost of the pumping station is based on $500 per water horsepower, the amount being adjusted slightly to scale down for the larger installations. Such costs are based on the known cost of the existing pumping stations in the city of Chicago. The cost of the settling tanks and appurtenances is based on careful estimates made from detailed drawings for a unit plant designed to care for 40,000 people. The appurtenances include a Venturi Meter, grit chamber, sludge drying beds, office building, laboratory, walkways, roadway, electric lighting, and the general appurtenances required. The cost of land has been estimated from actual cost of land purchased by the District for its right of way for channels, and current sales of real estate in the city of Chicago. In each case, an allowance has been made for the probable increase in future costs.

Q. What is the annual cost for the above scheme to provide treatment equivalent to flows of 10,000 cubic feet per second, 12,000 cubic feet and 14,000 cubic feet, assuming that only 4,167 cubic feet per second is permitted and allowed?

A. That annual cost is given in the table just submitted. The annual cost submitted upon the table last given by me in this case, is entirely independent of any present operating cost of the Sanitary District.

Q. In making up these annual costs, what have you included in your allowances, if anything?

A. The annual cost includes an allowance for labor, repairs and supplies for the operation of the grit chamber, settling basins, sprinkling filters, secondary settling basins, the cost of labor and supplies for the disinfecting plants; the cost of labor, fuel, supplies, and repairs for the pumping stations; depreciation on all structures; interest during construction at 4½ per cent. for the entire construction cost for one-half the period estimated for construction. The allowance however made on land is the interest on the cost for the entire period. In the making of the estimates for sterilization, chloride of lime has been used as a sterilizing agent for the effluent of settling basins and sprinkling filters, whereas liquid chlorine has been estimated for handling the storm flows, in order to have available a large potential supply of chlorine for immediate use on sudden storms.

Q. What is the capitalized cost of the foregoing schemes, including in your capitalization the construction cost, as well as the capitalized cost for maintenance, operation and depreciation?

A. These costs are given in the following table:

CAPITALIZED COSTS OF SEWAGE TREATMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Construction Cost	Capitalized Operating and Depreciation Cost	Gross Capitalized Cost
10,000	$72,884,471	$110,625,800	$183,510,271
12,000	87,200,000	132,941,100	220,141,100
14,000	101,900,000	155,058,800	256,958,800

Q. Are these costs in the table which you have just testified to supplemental to the present expenditures made by the Sanitary District which have been given by you as construction and operating costs?

A. Yes, sir.

Q. What are the combined total costs, covering construction and capitalized annual maintenance and depreciation, combining the existing investment of the District with the investment required to produce with a reduced flow of 4167 cubic feet per second the equivalent of conditions of flow of 10,000—12,000 and 14,000 cubic feet per second?

A. These are given in the following table:

CAPITALIZED COST OF SEWAGE DISPOSAL COMBINING COST OF NEW TREATMENT WITH EXISTING INVESTMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Capitalized Cost New Works	Gross Capitalized Cost of Existing Works to Dec. 31, 1913	Total Gross Capitalized Cost
10,000	$183,510,271	$76,067,600	$259,577,871
12,000	220,141,100	76,067,600	296,208,700
14,000	256,958,800	76,067,600	333,026,400

Q. What do you estimate the gross resources of the Sanitary District of Chicago to be in the period between 1914 and 1925, based on both receipts from taxes and sale of bonds, assuming that all construction work was stopped on December 31, 1913, and that only the necessary operations for maintenance and operation of existing works for sanitation were continued?

A. I have had studies made of receipts from taxes in the past by the Sanitary District, and a study made of the probable increase in the taxable value of property within the Sanitary District, so as to estimate the amount of bonds that can probably be issued by the Sanitary District, and from these have estimated what the highest possible income could be up to 1925, by issuing all of the bonds it is possible to issue, and getting all of the money from general taxation that it is possible to get, and the amount available from 1914 to 1925 inclusive would be $54,729,000 approximately.

Q. What is your estimate of the actual requirements of the Sanitary District aside from any works necessitated by fixing the available diversion, to round out unfinished details in connection with the present works?

A. I have compiled from the books of the District and from estimates the probable investments required in the next ten years to cover extraordinary repairs and to settle obligations on contracts, assuming that all existing contracts for construction are terminated on December 31, 1913. This includes the amounts necessary to complete the North Shore and Evanston intercepting sewers, to improve the Des Plaines River in the territory recently annexed, to adjust the conditions in the North Branch of the Chicago River, to build certain docks in the Main Channel, repair walls at Lockport and Joliet, and to carry a share of the expense of handling the industrial wastes. This amounts to $11,577,000. This would be deducted from the available resources given in my pre-

vious answer, this reducing the net amount available for new works to $43,152,000 approximately.

I am of the opinion that the amount of $11,577,000 would probably be too small.

Q. In your judgment, what time would be required to build the works covered in your estimates, if a diversion of 4167 cubic feet per second were assumed?

A. I should judge that if it could be done at all, ten years would be required, of which probably the first two years would be devoted to overcoming the inertia and making necessary studies in detail, financial and legal arrangements.

Q. Referring to your estimates of the financial resources of the Sanitary District, would you say that the District could finance the scheme which you have outlined in this working period of ten years, assuming that a diversion of 4167 cubic feet per second is allowed?

A. No, I do not believe it would be possible to finance this with the net revenue available. Not only would the construction costs have to be met, but also certain operating costs, as parts of the works were finished and put into service.

Q. Will you identify the report of Mr. G. M. Wisner, made on October 12, 1911, to the Board of Trustees of the Sanitary District; and will you briefly explain the premises on which it was made?

A. I have the report before me and it is a re-print from the original type of the original report published in the proceedings of the Sanitary District in the official issue of October 26, 1911; and that is the report made by me. In accordance with the instructions of the Board of Trustees, this report was prepared and was presented to the Board. The basis upon which the report was developed was the assumption that 10,000 cubic feet per second could be diverted. This was simply an assumption for the purpose of study, and to call the attention of the Board of Trustees to the need of considering carefully the future development of the District, if additional water above 10,000 cubic feet was not available.

This is made clear by conclusion 2 at the bottom of page 76, which states:

"The amount of water available for dilution, if taken at 10,000 cubic feet per second, will be insufficient after 1922, when supplementary methods of sewage disposal will have to be installed."

There is nothing in the report to indicate that an additional flow of 4,000 cubic feet per second would not be ob-

tained, or that this additional flow would not accomplish a better, more scientific and hygienically safer solution.

Mr. Wilkerson: I will move the answer be stricken out, on the ground it is unintelligible unless the report is in evidence.

Mr. Austrian: We offer so much of the report in evidence as the witness testified to.

Mr. Wilkerson: No, he stated the premises on which the report is made and the answer is utterly unintelligible unless the report is in evidence.

Mr. Austrian: We offer so much of the report in evidence, it having been heretofore referred to upon the cross-examination of numerous witnesses by the Government Attorney, we offer so much as embodies conclusion 2, at the bottom of page 76, in evidence.

Mr. Wilkerson: I move to strike out the answer on the ground stated.

Mr. Austrian: If the Government desires to offer the balance, that is up to them.

Mr. Wilkerson: The Government has no desire to offer it in evidence at this time, because it is not putting in its evidence; but the Government does object to any questions or answers relating to the premises upon which the report was prepared, or what the report means, or what the witness had in mind when he wrote the report, unless the entire report is in evidence, and will insist upon its motion to strike out any explanation of that kind, unless the report is first offered as the basis of the question. That is to say the Government does not propose to allow the witness to go into an explanation of this report, and then be forced, in order to get the statements in the report clearly favorable to the Government's contention in this case before the court, be compelled to offer the report itself.

Mr. Adcock: Q. Did you have, at the time when the report was made, any official or any other knowledge, which led you to believe that any agreement could be reached at that time by the District and the Government for a definite diversion; and what if any diversions had theretofore been discussed between the District and the Government?

A. At that time, the International Waterways Commission had recommended that no question be raised as to the right of the Sanitary District of Chicago to divert 10,000 cubic feet per second from Lake Michigan, and in fact no one had questioned the right of the Sanitary District to divert that amount.

At the time the report was made, I had no knowledge that any definite diversion was agreed upon. I based the report wholly upon the assumption that if a diversion of only 10,000 cubic feet per second were permitted, certain developments would be required, other than dilution. I knew that if 14,000 cubic feet per second could be secured that the construction of the developments proposed would be postponed by the extension of the dilution capacity due to the additional flow. I also knew that the extension of the diversion facilities of the District to cover the use of 14,000 cubic feet per second by the construction of the Calumet-Sag Channel and the enlargement of the small sections of the Main Channel was the most economical method of handling the sewage of the District up to the equivalent population.

I did, however, point out in my report, pages 75-76, that: "The extension of the capacity of the Main Channel in the manner indicated is, therefore, both reasonable and economical." This observation is, however, contingent upon a maximum diversion of only 10,000 cubic feet per second. It is however a much more costly procedure for the District than the use of the existing rock section up to its economical and full limit, that is a diversion of 14,000 cubic feet per second.

I purposely omitted all comparisons of cost with the existing methods of dilution, because I was not making a comparison of methods, but was endeavoring to show the need of careful study to solve a then unknown problem—that is, the means available in case a diversion of 10,000 cubic feet per second should be the limit.

Mr. Wilkerson: So that there will be no mistake at the hearing of this case, I still insist on the motion that the trial judge strike out this answer of the witness and fail to consider it unless the defendant shall have introduced the report in full in evidence.

Mr. Adcock: The report that you have been referring to is the document which I now hand you, and which we ask to be marked Wisner's Exhibit 5, for Identification.

A. Yes, sir.

(Whereupon the report of the witness was marked Wisner Exhibit 5, January 20, 1914.)

Q. What were your plans for the future extensions and improvements to the various works of the Sanitary District to take care of the increase in population?

A. It has always been my plan, since becoming Chief Engineer of the District to utilize the capacity of the different sections of the Main Channel to the full limit, and to have at

all times a flow of 10,000 cubic feet per second through the earth sections. The diversion to utilize the full capacity of the rock section was planned to come by the construction of a 2,000 cubic feet per second channel from the Calumet River to the Main Channel at the Sag, which could subsequently be enlarged to 4,000 cubic feet per second. These matters were presented by me from time to time to the Board of Trustees, upon whom I urged the construction of the Calumet-Sag Channel, as now being built.

Q. Will you explain briefly what was the nature of the report of October 12, 1911?

A. The nature of the report was of necessity preliminary, as it was prepared with considerable haste. The data presented on the physical condition of the district were substantially accurate, but it was realized that the estimates presented for the cost of the work would be subject to considerable revision, as the time and assistance available only permitted a very cursory study of the case.

The estimates were made on a conservative low basis, to indicate to the Board of Trustees a figure which would certainly have to be spent and would probably be materially exceeded, as our present figures show.

In the interval of two years, close attention has been paid to the movement of population. It has been found that certain areas are building up fast and that sites considered available two years ago are now out of the question. By sites, I mean locations for sewage disposal works.

My attitude is best indicated by the following from page 3 of the report:

"The sanitary aspect only of the problem is given consideration. Enough cost figures will be given to indicate the relative expense of the remedies suggested." And further: "At best this report is but a skeleton to start detail studies and designs so that the cheapest and most feasible method can be worked out for the handling of the sewage of the Sanitary District after the year 1920."

Q. Have you found in making your revised estimates that further allowances should be made which were originally omitted, and if so, and if so state?

A. In making the estimates of 1913, it was found necessary to increase considerably the cost of the settling plants and appurtenances because detailed study and the preparation of careful plans showed that the cost would be greater than anticipated from any known costs elsewhere where work was carried on on a smaller scale. It was also found that it would

be necessary to obtain much more land than was estimated upon in the report of 1911. Investigation of local conditions showed that construction costs would be somewhat higher, that the excavation required would be deeper than was anticipated originally, and that the appurtenances required for the careful operation of large plants would cost more than was originally supposed.

Further precedent was also available on the cost and design of sprinkling filters, which was taken advantage of in the later estimates.

In addition, more liberal allowance was found desirable from the study of our own costs and elsewhere for large projects, for the overhead charges, and an allowance for interest during construction which was not included in any way in the former estimates.

The costs of operation were also revised in the light of careful studies from such data as could be secured on known plants, and careful investigation of the local conditions of the Sanitary District. In preparing the estimates for the sewer costs, very careful attention has been given to the actual location of the sewers, their sizes and probable cost. Allowances were found to be necessary for the changes in public utilities in an intercepting sewer system to be constructed on such a large scale.

Q. What effect has the change from a diversion of 10,000 cubic feet per second to 4167 cubic feet per second on the estimates and methods?

A. It was known that a diversion of 10,000 cubic feet per second would suffice to prevent flood discharges of the Chicago River into Lake Michigan; therefore, no allowance was made for the disinfection of storm water sewage or the effluents of settling plants or sprinkling filters. With a diversion of 4167 cubic feet per second only, the complexion of the case is entirely altered, since there is a probability of a discharge into the lake for many days each year. It therefore becomes necessary to extend the installation of the equipment to include the sterilization of the storm water, settled sewage and sprinkling filter effluents, and to provide contact tanks for the retention of the storm water, as well as apparatus for sterlization, and the men to operate the sterlization devices. The smaller diversion also necessitates the construction of a very complete intercepting sewer system, with additional pumping stations and a much more extended treatment.

Q. In the interval from 1911 to 1913, has there been any great advance in the art of sewage disposal, if so state what?

A. There has been considerable advance in the knowledge of the conditions attending sewage disposal, and in particular of the precautions to be taken to avoid the production of anaerobic conditions, or nuisance, all of which have also increased the extent of the proposed works, and naturally increases the cost. The difficulties attendant upon the proper treatment of sewage have become more appreciated than they were two years ago or three years ago, whereas the methods of treating have not materially changed except to add to the treatment at that time supposed to be adequate, such as for instance the aeration of sewage and the disinfecting of the effluents coming from disposal works.

Experience in the actual operation of works since 1911, has demonstrated that the problem of sewage treatment is not a simple one. The development of the art points to the need of greater care and attention to works, design and operation, and to the need of conservative loadings and basis of design. The tendency of all this is to increase the cost of works, rather than to reduce it.

Q. What further investigations have you made since 1911, of the dilution ration and the effect of industrial wastes?

A. Immediately after the publication of the report, I arranged to have continuous study made of the condition of the canal at Lockport day and night, so that since that time samples have been taken at intervals of eight hours practically continuously. I have also had preliminary but careful studies made of the effect of industrial wastes, and the burden which they put upon the Drainage Canal. All of these studies have reinforced my judgment in forming a conclusion as to the handling of the sewage of the Sanitary District and the developments needed.

Q. Why is a diversion up to the full capacity of the rock section, viz.: 14,000 cubic feet per second, the most economical way of developing the resources of the Sanitary District for sewage disposal?

A. This is shown by the following table which shows the amounts which would have to be expended by the Sanitary District under the different alternative methods, first of dilution, and second of treatment, to produce approximately the same result in the treatment of the sewage. I do not consider, however, that this scheme for treating the sewage with

a diversion of 4167 cubic feet per second, and the use of the supplemental works, is as effective in protecting the water supply as the diversion of from ten to 14,000 cubic feet per second.

COMPARISON OF CAPITALIZED COST TO SANITARY DISTRICT FOR EQUIVALENT DIVERSIONS OF 10,000, 12,000 AND 14,000 CU. FT. PER SEC.

Existing Works plus Treatment on Basis of Diversion 4167 Cu. Ft. per Sec.	vs.	Extension Dilution from 10,000 to 14,000 Cu. Ft. per Sec.	
Equivalent Diversion of Cu. Ft. per Sec.	Existing Works with 4167 C. F. P. S. Plus Treatment	Extension of Dilution, Gross	Extension of Dilution, Net‡
10,000	$259,577,871	$76,067,600	$62,825,600
12,000	296,208,700	95,517,070	77,720,070
14,000	333,026,400	102,519,910	80,213,900

‡This allows credit for Electrical Dept. earnings.

Q. In basing your opinion on the efficiency of the various methods of sewage treatment, what factors have you taken into consideration, in reaching the conclusions concerning which you have just testified?

A. One factor is that of the known methods in 1887-1890, and even up to 1900. The present method of dilution is the only one available for handling the sewage of cities over 100,000 population, which has survived the test of time. We have definite knowledge of the workings of the Main Channel from 1900 to 1913, with the severe tests which actual continued use imposes. Of the alternate schemes, no one can show a continued use so long, nor an application on so large a scale.

Another factor has been the attitude of sanitary engineers and sanitarians in general. I know of no sanitary engineer or expert qualified to speak authoritatively who does not say that the diversion method installed at Chicago is the best method for that locality. This opinion I have found held not only by American but also by foreign experts.

For many years many engineers and others, particularly laymen, residing in and out of Chicago, had criticised the dilution method of sewage disposal, as exemplified in Chicago. In order to satisfy the Board of Trustees and myself on this point, I recommended the establishment of a testing station and finally was authorized to build one in 1909.

Mr. Wilkerson: I assume our general objection is broad enough to cover this specific point, that the last statement of the witness is purely hearsay and entirely argumentative

except as the statements of the experts appear in the testimony of this case.

Mr. Adcock: Yes; it is leading up to the result, that is the establishment of the testing station.

Mr. Wilkerson: I mention that point specifically because it is so apparent that it is all hearsay except as there may be in the record in this case the statements of the experts.

The Witness: This testing station has been running continuously ever since. The results obtained and the studies made on the canal and the Illinois River have only served to confirm my opinion that the method of diversion and dilution is the best, the safest, and the most economical for the local situation.

I might say that at this sewage experimental station at 39th street, and the second one at the Stock Yards, where the wastes of that industry are being tested, at these places we have tested out every known device that would be applicable to the treatment of sewage in this locality.

Q. You have outlined certain method by which sewage could be treated if the diversion were limited to 4167 cubic feet per second. How do you regard those plans from a practical standpoint?

A. As an engineer, I have had serious doubts concerning the practicability of works for treating sewage on such a large scale. This does not come from fear or ignorance of the correct principles to follow, but is based on conservatism, induced by lack of precedent anywhere for the partial or complete treatment of sewage on such a large scale. There are many novel problems involved. One of the greatest difficulties in the way is the securing of suitable sites. Judging by the opposition developed in Chicago recently in the various wards to the location therein of garbage treatment plants, I would anticiapte serious delay in obtaining the sites desired. Public sentiment, even though wrong, is slow to recognize the necessity of certain locations. Another condition that might work adversely to artificial sewage disposal is the climatic conditions of Chicago, where severe winter weather is encountered. Most of the plants that I have seen in operation do not have the severe winters that Chicago experiences.

Q. What economies have been afforded to the towns lying in the valley of the Des Plaines and Illinois Rivers below Lockport, due to the operation of the Main Channel of the Sanitary District?

A. So far as the towns in the Illinois River Valley, exclu-

sive of Joliet on the Des Plaines, are concerned, ample dilution has been afforded. It is possible that if only the natural flow of the Illinois River were available that the low flow would be insufficient today for the dilution of their sewage alone, provided local nuisances were avoided. Coarse screening and possibly sedimentation might have to be installed. The cost of this I have not studied, other than to note the probable need of additional expenditures over and above those now made for sewer systems. On the Des Plaines River, however, Joliet would have had an absolutely inadequate dilution, which would have necessitated complete treatment of the sewage at a probable cost, pro rated from our estimates for Chicago of about $1,000,000. This has been saved by the flow from the Sanitary District to the City of Joliet.

Q. What has been the elevation of the lakes before and after the opening of the Drainage Channel in January, 1900?

A. I have prepared a diagram which has been brought up to date, month by month, showing the lake levels at Chicago, taken from the publication of the United States Engineer's Office, and the Lake Survey, and corrected to date in accordance with the monthly bulletin issued from the office of the Lake Survey at Detroit. This shows that the average lake level for the 11 years following the opening of the canal was 580.63 elevation referred to mean tide at New York, or 0.22 of a foot higher than the average lake level for the 11 years prior to the opening of the canal, which was 580.41 elevation referred to mean tide at New York.

Q. You have referred to a diagram. I offer the diagram referred to in evidence as Wisner Exhibit 6 of this date. Is this Exhibit 6 the diagram to which you have referred, if so will you just state what it shows?

(Whereupon diagram referred to by witness was marked Wisner Exhibit 6, January 20, 1914.)

A. Yes, sir, it is. It shows the average monthly elevation of Lakes Michigan and Huron from 1899 to 1913 inclusive by the zigzag line tinted blue. The sides of the diagram show the elevations referred to the mean tide at sea level. The straight horizontal black line at the left of the exhibit, below which it is tinted brown, is the mean elevation for the 11 years prior to the opening of the canal, and the straight horizontal line with the reddish tint below it shows the average elevation of the lake from 1900 to 1910 inclusive, the 11 years following the opening of the canal. It shows during this entire period the highest point to which the lake has gotten in any

one month; also the lowest point; the lowest one being in 1905 winter of 1905 and '06.

Q. What effect if any has high lake levels on the cost of construction and operation of sewers in Chicago?

A. High lake levels will increase the cost somewhat of new sewers by reason of the ground water, but the principal influence is in retarding the efficient operation of the sewers by backing up the waters in the sewers to a greater distance from the mouth, and probably permitting thereby the stranding of solid materials which is very undesirable. The engineer in constructing the sewerage system plans to put the sewers at a certain depth below the surface to permit discharges of liquids from cellars and to get grades which will produce safe velocities at low flows. With the flat topography of the City of Chicago and the back water produced by the lake, it is extremely important to produce the best working conditions on the intercepting sewer systems, which necessitates pumping and great increased cost.

Adjourned subject to notice.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the rooms of the Sanitary District, Chicago, Tuesday, January 27th, 1914, at 10:30 A. M.

Appearances:

Mr. James H. Wilkerson, and
Mr. Albert L. Hopkins,
Representing the Government.
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian,
Representing the Sanitary District.

GEORGE M. WISNER resumed the stand and testified as follows:

Direct Examination (Continued) by Mr. Adcock.

Q. Mr. Wisner, who has assisted you in preparing estimates under the two projects that you mentioned, for works to dispose of sewage?

A. Mr. Langdon Pearse, Division Engineer, and Mr. Samuel A. Greeley, Assistant Engineer, and Doctor Lederer, to

some extent; he is our bacteriologist. And then there has been general work by others in the office.

Q. In general, what has been the scope of the work; the time that has been applied by yourself and others connected with the work?

A. I should say that Mr. Pearse and Mr. Greeley and myself have probably spent nearly two-thirds of our time on it since last February, preparing for this case and studying all sorts of possible schemes to take care of the situation, in case the flow was restricted to 4167 cubic feet per second; preparing estimates and getting up costs and data; finding out the data in regard to the death conditions in other cities; the condition of their water supply; and consulting with engineers and experts along sanitary lines, to see if we could develop a scheme that would approach in efficiency the present one. And we found we could not.

Cross-Examination by Mr. Hopkins.

Q. Who assisted you Mr. Wisner in the preparation of your report of 1911, which is referred to in your testimony and identified as Wisner Exhibit 5, dated October 12, 1911?

A. As I stated on page 3: "This report is largely based upon studies made at the 39th street testing station under the direction of Mr. Langdon Pearse, assistant engineer." He had a number of assistants, and Doctor Lederer there; and this report was the result of the studies that we made there, and my general knowledge of what was being done at other places.

Q. Were the estimates, costs, obtained in part from Mr. Pearse?

A. Yes, in part from Mr. Pearse.

Q. Did he agree with those estimates when they were made?

A. Those estimates at that time were made rather hurriedly. There was some disagreement on the Board as to the advisability of this report being made.

Mr. Hopkins: I object to that.

The Witness: For that reason we did not have as much assistance in the preparation of this report as we should have had.

Mr. Hopkins: I object to that and move it be stricken out as not responsive.

Mr. Austrian: Do you refer to the estimates in the report of October, 1911?

Mr. Hopkins: Yes, sir.

Q. Did Mr. Pearse study those and examine them?

A. Those estimates?

Q. Yes?

A. Yes, sir.

Q. Did he object to any of them that were put in?

A. There was no objection made to them. It was simply that we were trying to arrive at what possibly might be the minimum cost, and it was a little matter of policy to keep the estimates low.

Q. Did Mr. Pearse—

A. Mr. Pearse objected only to this extent, as I remember, that we both thought that we did not have sufficient data to give a detailed estimate that would be accurate. The cost was merely relative and preliminary to a detailed study of the projects outlined in that report.

Q. Then Mr. Pearse agreed with you in that report; you acted together?

A. We acted together. He was working under my direction and we worked together.

Q. There was no disagreement between you as to matters contained in that report?

A. There may have been some. I don't remember now.

Q. But on the whole he—

A. Generally I think we were pretty well agreed as to the policies outlined in that report, the conclusions arrived at.

Q. As a matter of fact you and Mr. Pearse did nearly all of the work in that report?

A. Oh, I think some of Mr. Pearse's assistants did considerable work in getting up tables and drawings.

Q. But if you and he had not approved of it, it would not have gone into that report, would it?

A. Oh no, it would not have gone in if I had not approved of the general policy of it.

Q. You have described in your direct testimony the intercepting sewers from 87th street to the south line of Evanston. When were they completed, to the extent of keeping sewage out of the lake?

A. Practically, on the South Side, in 1906, and on the North Side, in 1908. I believe there was one connection on the South Side that was not put in until 1910.

Q. What provision is made in those intercepting sewers for storm overflows now, if any?

A. We handle all the storm overflows.

Q. All of it?

A. We do not have any storm overflow. We handle the entire storm water.

Q. Then there is no water whatever that goes into the lake?

A. No.

Q. Between 87th street and Evanston?

A. Practically none.

Q. To what extent does any go in?

A. Well, possibly along the lake shore, between the lake shore and the sewers there may be a little water that runs in, but it does not amount to anything.

Q. It is the direct run-off of the land?

A. The direct run-off of the land right along the lake shore; park drainage might go in some, like Jackson Park and Lincoln Park.

Q. You do not collect the park sewage then?

A. Possibly some of it is sewered. I am not sure about that.

Q. In the summertime that would be quite an item, would it not?

A. In the summertime? I should think not.

Q. What was the additional cost of the Sanitary District works necessary to develop the power?

A. I have given that in my direct testimony, the cost of that; if you will refer to that.

Q. That is the item of about $5,345,241.57?

A. That is my recollection of about the amount.

Q. Was that intended to include everything, changes in the canal itself, dams and so on, which would assist in the water power development?

A. It was chargeable to that development.

Q. That is what I am after. Just what did you consider chargeable to the water power development?

A. Well, for instance, the lock that was put in down there was chargeable against the Calumet-Sag Channel. That was not charged against the water power development.

Q. What was the cost of that?

A. I would have to look that up for you. I can have that looked up for you.

Q. Where is that lock located?

A. Right adjoining the power house.

Q. Well, is it necessary for your water power system?

A. No, not at all.

Q. It has nothing to do with it?

A. No.

Q. Then you do not consider it properly chargeable?

A. Against the water power development, no.

Q. Your water power would be just the same without it?

A. Yes, sir.

Q. You need not look it up then?

A. It was not included in that figure, Mr. Hopkins.

Q. Go ahead; just what do you include in that?

A. Well, we included the power house, the electrical machinery, transmission lines sub stations, the excavation made necessary for the power development, construction of walls and embankments and cost of fixed bridges across the channel over this extension; cost for the tail race development. Generally that is it.

Q. Does it include everything which is additional to the necessary disposal of sewage?

A. No, there are certain charges that went in against the Calumet-Sag Channel, that it does not include, that was built at that time.

Q. The Calumet-Sag Channel is for the purpose of disposing of sewage, isn't is?

A. Yes. Under that, I should say it included that.

Q. Along towards night, the flow through the canal is increased, isn't it?

A. Sometimes and sometimes not.

Q. Isn't that rather the usual state of affairs?

A. I should not say it was the usual state of affairs.

Q. Don't you increase the flow, so as to increase your power a little at night?

A. At certain seasons of the year, we diminish the flow during the day time, and increase it at night time. That is only for, I should say possibly December, January and February; but we do not flow during the day an average of more than what is called for under the state law, even at that time of year.

Q. What do you mean, what state law?

A. The state law which prescribes that we shall flow 20,000 cubic feet per second for every 100,000 people draining into the channel.

Q. Do you have a diagram showing the low curve at the power plant?

A. We have one here in the office, I believe.

Q. How much water is necessary in cubic feet per second to develop the power that you are actually disposing of at this time?

A. Well. at certain times Mr. Hopkins, so that you will not go wrong, when our peak load, which is the high load of our power is on, we help out our peak load by running steam plants.

Q. That is you—

A. We develop power by steam, to help out on the peak load.

Q. Where are they located

A. There is one at South Park, Washington Park; there is another, an old city station, called the H. N. May plant; and I believe there are possibly one or two others that we can use.

It is the old city municipal electrical plant that we use, and the Washington Park electric plant, which, after we got to furnishing them electricity they turned over to us for our use.

Q. So that the amount of water you are actually taking through the canal now is not sufficient to develop all the power that you dispose of?

A. Not at times of the peak load.

Q. This Washington Park plant lights the South Parks, doesn't it, Washington and Jackson Park, the Midway?

A. It can be connected up with our system. It only lights it, or helps to light it at the time of year when the peak of our power load is too great for the water flowed to develop.

Q. What part of the year do you run the supplemental station?

A. During the months that I spoke of, December, January and February, and then not all the time.

Q. What part of your power is used in lighting streets, and what power in the pumping stations; what part is sold for commercial purposes?

A. I don't know how much is given to each department.

Q. Do you have it in mind approximately?

A. No, I have not.

Q. Is there any publication of the Sanitary District which shows that?

A. There may be, but I haven't it in mind.

Q. What kind of a record do you keep of that?

A. That I am not very familiar with, Mr. Hopkins. It comes under the electrical department, and I am not an electrical engineer.

Q. Do you know how much power you have at Lockport

for 4,167 cubic feet of water a second; how much you can generate with that supply of water?

A. I could get that for you.

Q. Will you do that?

A. Yes, I will have that figured.

Q. And for 7,500 cubic feet and for 10,000 cubic feet?

A. Under present conditions?

Q. What conditions would make a difference?

A. Well, there might be some improvements made in the Drainage Channel itself that would increase the power without increasing the flow.

Q. Would that change any condition, interfere with the current?

A. Why it might lessen the current.

Q. Whatever conditions you call most favorable to the Sanitary District, I would suggest. In your direct testimony, in speaking of the benefits from the direct Drainage Canal, you spoke of power along the Desplaines and Illinois Rivers?

A. Yes, sir.

Q. Just what power is there now being developed along those rivers?

A. There is one place right at the junction of the Kankakee where they are trying to develop it, but I believe the government is trying to stop them from doing it.

Q. That is the Economy Light and Power Company?

A. Yes, at Dresden Heights. There is power being developed at Marseilles.

Q. How much?

A. I don't know.

Q. Isn't Marseilles below the Kankakee?

A. Yes, sir.

Q. What is the head at that place?

A. I don't know.

Q. Any other power plants along the Desplaines or Illinois?

A. No, but there are places where it is possible to develop power.

Q. Where are the other places?

A. That I would have to look up. There have been several schemes, some of them I think were reported upon, one has been reported upon by Mr. Randolph of the Internal Improvement Commission; another one by Mr. L. E. Cooley; and I believe the government engineers themselves have reported upon a deep waterway and power development.

Q. Do you know about the amount of power that was estimated they can develop along there?

A. I did know, and I can look that up for you, but I haven't the figures in mind now, Mr. Hopkins.

Q. I wish you would look that up.

A. There have been several estimates made.

Q. Do you know to what extent the development of such power plants would interfere with the navigability of the streams?

A. It would not interfere. I think it would tend to be a benefit to the navigability of the streams.

Q. In all cases?

A. I do not see really that they would be of any harm.

Q. In each case they would have to have a dam and locks?

A. Yes, sir, that is true, but in developing these powers they would get greater depth, and improve all the slack water navigation, and would make the river at certain places where now it is practically not navigable, would make it navigable.

There is power being developed at Joliet. I neglected to mention that.

Q. On what river?

A. On the Desplaines.

Q. How much?

A. Well, they have got a very inefficient plant. I presume they have got in the neighborhood of 3,000 horse power that is being developed there now.

Mr. Austrian: I think the record ought to show that none of this power that the witness is speaking of is being developed by the Sanitary District.

Mr. Hopkins: Q. Now, you say the Sanitary District has expended approximately eleven and a half million dollars in the improvement of the Chicago River. That includes the North and the South Branch, but is exclusive of any work done on the canal itself

A. Yes, sir.

Q. Just what proportion of that was spent before January 1st, 1900, and what part after January 1st, 1900?

A. I would have to have that looked up; I haven't it in mind, it is so long ago, Mr. Hopkins.

Q. Will you have a table prepared showing in a general way those expenditures by years, and what they were for?

A. I will. It may take some little time to get that up. I think I can get it, though.

Q. You can get without much trouble the amount that was spent each year, can't you?

A. It will mean going through the books by the bookkeeper and picking out the amounts expended on that account.

Q. I think we would like to have it, what was spent by years, at least what part of that $11,500,000 was spent before May 8, 1899?

A. It might be impossible to divide it on that date.

Q. You can give it though, you think, by years?

A. I think I can get it up that way.

Q. Do you know whether there was much spent in the Chicago River between May 8, 1899, and January 1st, 1900?

A. There might have been quite a little expended at that time.

Q. But if we get the annual, we can approximate what was before that time and what was after?

A. I don't know whether you can or not.

Q. Just what will you furnish?

A. I will try to furnish what you ask for, Mr. Hopkins.

Q. Was any of the expense or cost that you have given in regard to the Calumet-Sag Canal spent before May 8, 1899?

A. I doubt it Mr. Hopkins, unless possibly there had been some survey work done that was chargeable against that project, some engineering work; and of that I am not certain.

Q. What part if any of it was spent before March 14, 1907?

A. That I can't tell you unless I look it up or have it looked up.

Q. Will you look that up?

A. I will do the best I can.

Q. As near as you can, if you cannot get it definitely?

A. I will see if I can get anything on it.

Q. Was the cost of that North Shore Channel included in the $11,500,000?

A. Of the North Shore Channel?

Q. Yes?

A. No, sir, the only thing north of the main river that was included in it was the improvement of the Chicago River from Belmont avenue to Lawrence avenue, of which I spoke in my direct testimony. The North Shore Channel was not included in that sum.

Q. Do you know what part of the $6,275,000 spent by the City of Chicago was spent before the opening of the Drainage Canal, and what part afterwards?

A. No, I do not.

Q. That was spent, you say, for dredging the river, including its branches, and for bridges and docks principally?

A. That is my information in regard to the matter. They may have bought some property too.

Q. For the purpose of the harbor for the city, and its navigation, and for crossing the river, all of those expenditures would be made, regardless of whether there was a sanitary canal or not, wouldn't they?

A. I do not know.

Mr. Adcock: You mean by the City of Chicago?

Mr. Hopkins: Yes.

The Witness: I don't know whether they would be or not.

Q. Do you have any reason to think that the diversion of water through the Sanitary Canal made any difference whatever as to the amount spent by the city in improving the river and building bridges?

A. It might have in regard to the building of bridges, Mr. Hopkins.

Q. In what way?

A. Getting wider openings, so that there would be a freer passage of the water in the South Branch.

Q. The city as such was not concerned in that, were they?

A. They were working in harmony with the Sanitary District, as far as that is concerned.

Q. That phase of it was really a Sanitary District matter, wasn't it?

A. Well, the City of Chicago is just as much interested as the Sanitary District.

Q. Except that they turned over the Sanitary feature of the city to the Sanitary District?

A. Yes, but they did build the bridge openings wider, probably on account of the current, wider than they would otherwise.

Q. As far as navigation is concerned, you speak of the stretch from Lake street to Ashland avenue as the critical point?

A. I would not call it a point, but the critical place. Of course there are places on the North Branch that are pretty difficult for navigation, on account of the river being crooked; but before we did any work the South Branch, that stretch, was the critical place.

Q. As far as current is concerned, though, if you were

flowing 8,000 cubic feet a second through the river, that would be the part of the river that would be critical?

A. As far as current is concerned, yes, sir.

Q. When you speak of the current not exceeding a mile and a quarter per hour, you speak of the mean current?

A. Average current, yes, sir.

Q. Do you have any figures of the maximum current in the river?

A. No, I have not.

Q. In mid-stream, that current would be much higher than this mile and a quarter you speak of, in order to get an average?

A. It might not be much higher. I think it was some higher.

Q. It was probably in excess of two miles per hour, wasn't it?

A. I think not.

Q. Just what is the cross section of the river from Lake street to Ashland avenue at its narrowest place?

A. I presume the narrowest place is right opposite Jackson boulevard and the Metropolitan Elevated, where it is, as I recollect, 90 some odd feet in width, and it is dredged, I think to about 26 feet.

Q. 26 or 36?

A. 26 feet, maybe a little deeper in places; and Jackson boulevard bridge is now being taken out. It is to be replaced by a bridge which will give sufficient openings so that the current will not exceed a mile and a quarter an hour. The contract is now let for it; and the Metropolitan Elevated bridge, as I understand, has been ordered out by the Secretary of War.

Q. At present then the width is 90 feet?

A. 90 some odd feet, as I recall.

Q. And with the new bridge in at Jackson boulevard, what will be the width?

A. It will be 168 feet, as I recall it, in the clear, and in addition to that there is a by-pass back of one of the pier abutments.

Q. 168 feet?

A. Yes.

Q. After those bridges are taken out, what will be the narrowest place?

A. Other improvements may be made by that time, and I can't tell you what would be the narrowest place.

Q. Do you know anything about when this Jackson boulevard bridge will be out, then, how long it will be before we will get this?

A. I think the specifications provide that the old bridge shall be out next spring some time.

Q. How about the Metropolitan bridge?

A. That I have no control of. I understand that the Secretary of War, as I stated, has ordered it out. When they will take it out, I don't know.

Q. What is the width of the Metropolitan bridge?

A. Practically the same as at Jackson boulevard. I should say they are only 75 feet apart, or 100 feet.

Q. Will the mere removal of that bridge remedy the condition between Jackson boulevard and the Metropolitan bridge; what is the width?

A. That we have widened and dug out back to the wall of a by-pass that is in back of the abutment of the Metropolitan and back of the center pier of the Jackson boulevard bridge.

Q. Aside from those two, what is the narrowest point in the river?

A. Well, Van Buren street, just below that, that is somewhat wider I believe than these two places.

Q. How much?

A. And it has a by-pass back of the abutment which gives additional available width for the flow of water.

Q. Do you know what that width is?

A. Of the by-pass, you are referring to?

Q. No, the main channel.

A. I am speaking from memory, and my recollection is that the opening of the Van Buren street bridge is about 110 feet and then there is a by-pass of about 50 feet in width.

Q. As a matter of fact, if you had 8,000 cubic feet of water a second flowing through there, there would have to be a great deal of widening to hold the current down to one and a quarter miles per hour?

A. Not very much. There are a few places which would have to be widened, and which we expect to have completed within a year.

Q. What cross section would you consider sufficient to get the result of a mile and a quarter an hour?

A. In square feet?

Q. Yes?

A. I will figure that for you. I haven't it in mind. On a diversion of 8,000 cubic feet per second?

Q. Yes?

A. Approximately an area of 4,360 square feet.

Q. Assuming a depth of 26 feet, then you would need a width of over 160 feet wouldn't you?

A. Yes, that is so, if you didn't have it any deeper than 26 feet.

Q. Is the river any deeper than 26 feet?

A. It is in places, yes, sir.

Q. How much deeper than that?

A. There are places where it is 28 or 29 feet in depth.

Q. That would not reduce the cross section very much, I mean the width?

A. It would not increase the width very much, but it would increase the cross section somewhat.

Q. And that would be on the assumption that the channel is rectangular in shape?

A. That would be on that assumption, yes.

Q. If the bottom sloped to a depth of 26 or even 28 or 29 feet in the middle, and sloped out, you would require much greater width?

A. Require a little greater width, if we had the 26 feet throughout its entire width, 26 feet or deeper.

Q. Do you have in mind any estimate as to how much excavating it would take to make the river all along so that the narrowest point will not be less than this cross section that you have estimated?

A. No, I haven't that figure in mind as to how much it will cost.

Q. Do you have any idea?

A. Not offhand. I think I made an estimate of that kind at one time, but I don't remember it now Mr. Hopkins.

Q. That would be a proper thing to be considered in the expense of the Sanitary District, if it were given the 8,000 cubic feet through that channel, wouldn't it?

A. My recollection is that I included that in the money that would be necessary to be expended.

Q. Where do you include that?

A. No, I think I am mistaken about that. I do not think that was included.

Q. Where does this mile and a quarter to a mile current come from, where is the idea of that, from the Secretary of War?

A. Yes, sir.

Q. Do you know in what permit it is included?

A. I don't remember which one now, but it was one of the early permits. The permits were changed from time to time, and as I recollect it was the—

Q. Do you know what the wording of that was?

A. My understanding was that the mean current should not exceed the mile and a quarter per hour.

Q. Was it the mean current, or that the current should not exceed a mile and a quarter per hour?

A. My impression is it meant the mean current; whether it said the mean, I am not certain at this time.

Q. Your figures have been based upon the idea of a mean current?

A. Yes, sir.

Q. If it were a maximum current of a mile and a quarter an hour, that would make the amount of widening much greater, or the amount of excavating?

A. The project for flowing 8,000 cubic feet on the 200 feet scheme has an area of 4,700 square feet. As I stated in one of my previous answers, to have an average current of only a mile and a quarter an hour requires about 4,360 square feet, so there is some excess on the completed project of a 200-foot channel.

Q. Do you have any idea what the cost of excavation to that extent would be?

A. It has practically all been done Mr. Hopkins except in three or four places; small distances along the river. And I think there are four of them that remain to be completed, negotiations for which are now being carried on, and these obstructions should be removed within the coming year.

Q. The Sanitary District, through contractors, is now actually engaged in digging the Calumet-Sag Canal?

A. Yes, sir.

Q. Along the line of the original survey?

A. To what do you refer as the original survey?

Q. The one that you outlined in your answer to the first bill filed in this case?

A. I should say practically along that line. There may have been some minor changes.

Q. The first addition to the Sanitary District was made in 1903?

A. Yes, sir.

Q. The original area was 196 square miles approximately?

A. I gave it in my direct. I haven't the figures in my

mind now. I can give them to you, right here, if it is of any benefit to you.

Q. No, I think we have them on record here.

A. No, it was 185 square miles, the original.

Q. Did you include what population has been added to the district, from the time that those areas have been added?

A. In the table on page 2072 of the record, it gives the populations.

Q. Well, does that give the population of the district as it originally was, the 185 square miles?

A. If you will notice, it gives two figures for 1902, and on that page it says, "Territory annexed" and then gives 1903 again. The same in 1913.

Q. You speak of the mussel industry of the Illinois River. Do you have any way of knowing that the increase in the mussel industry is due to the Sanitary Canal; or is it simply that you find they are getting more mussels down there?

A. Only from seeing the records and from talking with the people interested in the industry, and general information that I find in regard to that.

Q. That is they have gotten more mussels down there in recent years than they did before?

A. They have, and that is the opinion of men engaged in that industry, that it has increased the supply since the opening of the canal.

Q. Have you compared it with the mussel industry at other places?

A. No, I have not.

Q. As to whether or not there is any greater demand for mussel shells in making buttons nowadays than there used to be, have you taken that into consideration?

A. No, I have simply gone on what I learned from people engaged in that industry.

Q. Just some general hearsay?

A. That I would not say was general hearsay. It was from men that ought to know something about the business they are engaged in.

Q. What do you mean by the figures in that column (record page 2072) "Actually tributary M. C."?

A. That is as near as I could estimate the actual population that is draining into and through the Main Drainage Channel.

Q. That really are draining into it? Or do you mean they are in a position where they can?

A. Where they do drain into it. Some of them may drain into the branches of the Chicago River; but it goes through the Main Drainage Channel, the sewage coming from that population.

Q. Now in your last column you state, "actual flow," is that actual flow or is it only computed?

A. That is the actual flow that would be required under the state law.

Q. Well then, are you flowing that much?

A. For some period back, we are flowing practically that much, yes.

Q. For how long a period back?

A. That I can't tell exactly because, as I stated in my direct testimony, our water wheels acting as meters have not given correct results.

Q. I understand, in your direct testimony you thought they under measured a little?

A. I do think so, as far as the actual flows are concerned.

Q. Don't you know how long you have been taking approximately this amount?

A. During the last year and 1912, and part of 1911, I think we have been taking about the amount as near as I can tell; prior to that, not quite as much.

Q. That would be at least 1912 and 1913, and you think in 1911?

A. 1911 may have been just a little shy, and 1910 possibly.

Q. You have taken at least as much as the figures indicated in this last column?

A. No, I think not except possibly this last year.

Q. 1913?

A. 1913. Before that it might have been somewhat shy.

Q. As a matter of fact you took as high as 10,000 cubic feet at times?

A. For a short time we might have taken as high as 10,000 cubic feet for a short time; I mean a few hours.

Q. That is a few hours in a great many days. You do not mean just two or three hours at one time and that was all?

A. That is what I mean, yes, sir.

Q. Had that simply occurred on one day?

A. Oh no, it has occurred on several days, but only for two or three hours at a time; and on that same day there would be probably times when we would not be flowing over 5,000 cubic feet a second, possibly less.

Mr. Adcock: Q. Would that be in the winter time?

A. In the winter time, as I stated before, when this heavy peak load comes on; but the average for the day has not exceeded—

Mr. Hopkins: Q. That peak load, you mean in reference to the power?

A. In reference to the power, yes, sir.

Mr. Adcock: Q. The daily or yearly average has not exceeded the amount provided for in the state law?

A. No, sir. There might have been times, Mr. Hopkins, when there were heavy floods due to run-offs of the Chicago River basin, when we ran 10,000 feet for a considerable length of time. That was simply to keep the Chicago River from going into Lake Michigan; taking the pollution out into the drinking water.

Q. How do you handle that flood water, keep it out of Lake Michigan?

A. We keep on increasing the flow so as to prevent the river from going into Lake Michigan.

Q. That is gaged at Lockport?

A. It is gaged at Lockport, yes, sir.

Q. In what way is it indicated to the man stationed there how much to open it?

A. We indicate from this office. As a matter of fact, there have been times when it got away from us and did go for short periods into the lake.

Q. Then you do watch the floods, and the rains in general and indicate to the man to increase the flow?

A. We do, if it looks as though there was any danger of the water going into the lake.

Q. With what success is that operation carried on?

A. In the last few years, we have prevented it; but in the earlier days of the Drainage Canal there were several times when it got away from us and got into the lake before we could increase the flow sufficiently.

Mr. Adcock: Q. That was when the flow was low and did not approach the maximum?

A. Yes, sir, and before the Chicago River was improved.

Mr. Hopkins: Q. Do you think the size of the flow makes very much difference as to your ability to take care of floods, if you increase it with your system of opening the gates at Lockport?

A. I really don't quite understand that question.

Q. Would it make any particular difference in taking care

of flood waters whether you were flowing 4,167 cubic feet average, or whether you were flowing eight or nine thousand cubic feet?

A. Yes, indeed.

Q. In what way?

A. In this way: If we would be flowing 8,000 cubic feet, a flood that would only produce that run-off in the Chicago River Basin would not reverse the current in the main river.

Q. You mean that you would have more floods you would have to watch?

A. We would have more floods we would have to watch, and the time it would take to get up a current or a discharge to reach the volume of the run-off would be shorter.

Q. What do you consider is the time required in order to create a current, increase your current from Lockport?

A. Say from 4,000 up to 10,000 cubic feet per second, so that the effect would be felt here in Chicago?

Q. Yes, to that full amount?

A. I speak approximately, but I should say to get the full effect of that would require in the neighborhood of from 7 to 9 hours.

Q. To get most of the effect, not the full effect?

A. Most of the effect, there would not hardly any of the effect be felt inside of four or five hours in the Chicago River, around the junction of the North Branch and the South Branch.

Q. What is the capacity of the flow at Lockport?

A. At Lockport?

Q. Yes?

A. 14,000 cubic feet per second.

Q. If you opened up everything wide how long would it take you to get an effect of 10,000 cubic feet, in Chicago?

A. The whole channel hasn't that capacity. Don't misunderstand me: You asked about the channel at Lockport.

Q. Yes.

A. I should say from 7 to 9 hours before we would get 10,000 cubic feet going through the river. I get that Mr. Hopkins from the fact that in the past there have been vessels stuck at different parts of the river, and we would have to shut off the flow at Lockport so they could get out of their predicament; and from observing that condition, we noticed any rising in the water in the Chicago River would be 4 or 5 hours after the works were closed down.

Q. Have you made any tests of the converse?

A. Of the converse?

Q. Yes, opening it up instead of backing it up?

A. Only as I have had them watch it the same way, after we had closed it off, to see when the current would start up perceptibly, and it seems it would be about the same length of time. Of course there are times when the influence of the lake level, the lake rising and falling, has an effect; but as near as I could judge 4 or 5 hours was required to feel the effect of opening or closing the works there in the Chicago River.

Q. If a careful watch were made and reported to Lockport, and an attempt made to keep the water out of Lake Michigan, what percentage of the time do you think there would be any flow into Lake Michigan?

A. With a flow of how much?

Q. 4,167 cubic feet?

A. I should say there would be probably 6 to 10 days a year when it would go into the lake.

Q. Out of those 6 or 10 days, I understand those are days —that is a very liberal estimate of the number of days on which the flow would reach 10,000 cubic feet in the Chicago River?

A. No, it would be the number of days it would exceed 4,167 cubic feet.

Q. Well, then, do you figure that every time it exceeded 4,167, some would get into Lake Michigan; that with your lookouts you could not prevent that most of the time?

A. I am assuming that we have a flow of only 4,167 cubic feet through the regulating works at Lockport?

Q. Assuming in connection with that you are permitted to open them up to a greater capacity at Lockport sufficient to take care of flood water so as to keep the Chicago River reversed?

A. In that case, I would have to open them up every time there was a rainstorm, because one cannot tell at the beginning of a rain whether it is going to cause a run-off of over 4,167 cubic feet per second in this basin, or not. It may not get to that amount; it might exceed it greatly. And you cannot tell until after the rain comes. The rain does not come in two minutes; it lasts over several hours, often.

Q. By so doing, and anticipating it, then what do you think would be your result? Couldn't you at all times in that way keep the water out of Lake Michigan?

A. It might be possible to do that, because we are doing

that now; but it would involve keeping observers all over the District, and it would involve increasing the flow when, as I have already stated, the run-off might not come anywhere near being 4,167 cubic feet per second.

Q. That excess that you would take for a few hours would not be very much would it, in case your rain did not come up to your anticipation?

A. During the course of the year it would amount to considerable.

Mr. Austrian: Q. You would have to anticipate it 5 or 6 or 7 hours in advance, wouldn't you?

A. You would have to anticipate the rainstorm, so that you would get your flow up; otherwise it would get away from you, because, as I stated, to get your flow up it takes 7 to 9 hours.

Mr. Hopkins: Q. How long do you think it will take the water from a rainstorm generally over the District to get into the river?

A. There have been floods around here where it has come in inside of 5 or 6 hours with excessive rains. Some of it comes in quicker than that.

Q. Then you would not have to anticipate it over 2 or 3 hours?

A. Oh, yes, you would; you would have to anticipate it, over and above the rainstorm, and you have to anticipate the rainstorm. You do not know whether you are going to get that kind of a flood or not; so it means you have got to anticipate it nearly nine hours, as I understand your question.

Q. But still it takes 5 hours at the least for the water that falls on the ground to get into the river?

A. That is to get up a big flood in the Chicago River.

Q. That time can be used in getting the flow reversed, so that your margin is only about 4 hours?

A. No, you have to anticipate the rainstorm, too.

Q. By a short time, much shorter than you say?

A. No, I think not.

Q. And with the assistance of the weather bureau, couldn't you anticipate big rainstorms to the extent that there would be a very small proportion, if any, of the water going into Lake Michigan?

A. No, I think not. There is no denying that the Weather Bureau is a help, but they cannot prophesy whether you are

going to have a rainfall of half an inch or two inches or a quarter of an inch. At least I have never seem them do it.

Q. I am assuming that you anticipate the rainstorm, if you consider it necessary to do so?

A. In which case I say we should have to start up our flow about 9 hours ahead of the time that we needed it.

Recess to 2:00 P. M.

After Recess, 2:00 P. M.

GEORGE M. WISNER, resumed the stand for further cross-examination by Mr. Hopkins and testified as follows:

Q. I believe you say that the typhoid fever death rate in Chicago is less even than in those cities that have filtered water?

A. That in many cities with filtered water.

Q. That rather indicates that there is something else that has to do with it besides water, doesn't it?

A. Well, the marked reduction in Chicago has been due to the improvement in the water supply.

Q. How do you know?

A. Because other municipalities situated the same as Chicago have not had the improvement found here.

Q. They have had some improvement haven't they?

A. And the conditions surrounding them are practically the same as in Chicago, with the exception that they are getting an impure water supply.

Q. How about the cities with filtered water, again, your own suggestion?

A. How about them, what?

Q. Why is it that that death rate is higher than in Chicago?

A. I do not know the exact reason for that, unless possibly the filters are not working as well as they should work; and there may be some other causes that bring this about. It may be that the filters are not doing the work they are supposed to do, although they have made improvements over and above the condition before the installation of the filters.

Q. As a general proposition, wouldn't a city that has filtered water have purer water than Chicago?

A. Not necessarily, from a bacteriological standpoint, at times.

Q. You have certainly some contamination of the Chicago water?

A. It may look better at times, when the water here is very turbid, but as far as its safety in drinking is concerned, we cannot discover that it is dangerous or unsafe.

Q. You simply charge the decrease in typhoid fever death rate to the water supply?

A. I think that is the principal cause of the decrease.

Q. You do not give any consideration to advance in medical science in the way of curing?

A. That probably has had something to do with it.

Q. Milk infection?

A. Typhoid fever is simply a disease in which the patient has to be nourished, rather than have any medicines, that one could take; and in cases where the milk supply has been watched, that tends to improve conditions, too.

Q. Vaccination?

A. Vaccination, that has only been done in recent years, and has not been done to any etxent in the City of Chicago.

Q. The crusade against the flies?

A. I do not think the flies have been done away with to any extent in the city.

Q. Did I understand you to say awhile ago that you regarded the water supply of the City of Chicago to be in as good condition bacteriologically as it would be if it were filtered?

A. I would like to have you pursue that assumption a little bit further, as to whether our system is in operation or not.

Q. With the conditions as they are to-day?

A. Would the water be pure if it was filtered, in addition to the Drainage Canal working, and keeping the pollution out of the lake, is that your question?

Q. As far as bacteria are concerned, yes.

Mr. Austrian: Q. Do you mean if the Sanitary District Canal was not in operation, and we filtered the water?

Mr. Hopkins: Just as it is today, would filtering help the conditions today as far as bacteria are concerned?

A. Well, it would certainly tend to reduce the number of bacteria and make the water safer where it is now contaminated, like for instance the 68th Street Crib, where the water supply is contaminated at times from the flood discharges of the Calumet River; and possibly sometimes from the sewage coming from the Indiana towns.

Q. And from vessels?

A. Vessels are being kept pretty well away from the cribs now. The last year or so, we have taken this matter up with the vessel owners, and they are giving instructions to keep the vessels away from the cribs. That is a source of pollution, but it is a thing that can be overcome by regulation, without causing any great burden on the shipping interests.

Q. What percentage of bacteria in water can be taken out by the filtering process?

A. I think that would depend to a large extent on the number you had to start with.

Q. In what way would that affect it?

A. I mean if there were more bacteria in the water, the chances are you would take out a larger percentage than you would if there were a very small number.

Q. Suppose that the sewage were dumped into the lake direct at Chicago, and you had a good filtration plant, what percentage of the bacteria would be taken out?

A. I really don't know. I know it would overburden the filters and would be unsafe, I am afraid.

Q. Suppose you treat it with hypochlorite of lime?

A. Well, that would help, but that is objectionable as it is apt to create a taste that is objectionable to the consumer. They are having a great deal of trouble with that most every place they are using it.

Q. Couldn't you filter your water, or treat it to an extent that it would be reasonably pure hygienically?

A. I think you could probably do that but there would be times when it might be unsafe. You are depending upon human agency; and I could only judge by what has happened at other cities. They are not having as good results as we are with a few possible exceptions.

Q. Have you got that chart Exhibit 3, whereon you figure out what we are all worth?

A. (Witness produces same.)

Q. Your Exhibit 3, shows graphically, or is supposed to show graphically, certain costs to the community. It is first dependent upon your assumption that a life is worth $10,000?

A. That is one of the assumptions, yes, sir.

Q. What is the basis of that assumption?

A. We took that because that is as I understand it what the statutes provide in case of accidental death.

Q. Who is "we." You said "we took that."

A. I mean this office, in figuring this up, the engineering department here.

Q. That is an engineering figure, that $10,000?
A. I said we got that from the statutes.
Q. What statute?
A. The Illinois death—
Q. Do you know what particular statute you are referring to?
A. I don't know the particular statute, but I think you understand what I mean. It is in case of death by accident that the employer would have to pay to the extent of $10,000 for a death.
Q. You mean the statute of Illinois making the maximum recovery in case of death by wrongful act $10,000?
A. Yes; I don't know whether it is wrongful or not.
Q. Did you have in mind that prior to ten years ago the maximum limit was $5,000?
A. Yes, I knew that.
Q. If you are going to take that assumption, a life over ten years ago was not worth as much as a life today?
A. I am taking what it is worth today, not ten years ago.
Q. Was it called to your attention that under the Workmen's Compensation Act, the maximum amount recoverable for death was $3,600?
A. No, that was not called to my attention.
Q. Now as a matter of fact there is no way of valuing the life of a person at all?
A. I should think that $10,000 was not too much.
Q. Isn't it simply an arbitrary matter founded on the statute?
A. (No response.)
Q. Now in this Exhibit 3, by that top line there you mean to indicate that if you had a very high death rate all the time, as you did between 1890 and 1893, and you valued each life at $10,000, that it would have cost the community—that would have been the loss to the community, the difference between that line and the lower one, on that assumption.
Q. Suppose you assume an epidemic period, and assume that it is not checked but goes on, you could get that kind of a line most any time, couldn't you?
A. Not under our conditions, we could not get an epidemic of that kind.
Q. I was assuming an epidemic period, you could get such a result as this?
A. We do get such a result, right on that chart.
Q. Was it called to your attention that that $10,000 pro-

vision had no reference whatever to a loss to the community, but was simply a loss to certain individuals?

A. Well, that was not called to my attention, but I understood that. There had to be some assumption made, the way I was getting at it, as to the value of human life.

Q. You think it is possible in dollars and cents to value human life to the community?

A. I think it is, yes.

Q. Just what is your basis for that?

A. A basis as to whether you take arbitrarily $10,000 as the value of life, I do not say that necessarily follows, but I think economists—

Q. That is what you said wasn't it?

A. Just a minute—I think economists have figured out that human life is of value to the community, and goes to make up the wealth that a community has.

Q. Doesn't that depend somewhat, very much in fact, upon the demand for population?

A. Well, we are talking about this particular country.

Q. You think you can go on indefinitely increasing people and the value of lives, at so much per head?

A. It depends upon whether there is room for them, I presume and whether they are educated people, such as the American people are.

Mr. Hopkins: Motion to strike out Wisner's Exhibit 3.

Q. How did the state, if you know, arrive at that figure of 3⅓ cubic feet per thousand inhabitants?

A. Generally it was arrived at, I think, as a kind of compromise.

Q. I mean what was the basis of it?

A. After consultation with experts and getting their views. I think they varied as to the amount that was necessary, from something like 2½ cubic feet per second per thousand people up to over four. And there were some experiments, I believe, made at that time; and they finally arrived, they thought 3⅓ would be sufficient. And if I remember, the law states that the dilution shall be at least 3⅓, giving some leeway to go above that, but that was thought to be the minimum that would properly dilute the sewage coming from a thousand people. There was not much reliable data at that time to go on, and it is remarkable, I think, that they guessed as well as they did at that time.

Q. Well, isn't that estimate based in a large part upon experiments and the experience of other cities?

A. There has never been any very careful experiment made, and what they did have was based upon the waters of rivers, which was not as good water for dilution purposes, oft times, as is the water of Lake Michigan.

Q. Then Lake Michigan is exceptionally high in oxygen?

A. It is as compared with a lot of rivers. It is not exceptionally high as compared with the waters of Lake Superior or Lake Huron or Lake Erie, if the temperature is taken into consideration.

Q. The ratio as determined was based in part upon experience from rivers at various places, wasn't it?

A. That I would hardly be qualified to say, as to whether in arriving at that they did not take into consideration the fact that the oxygen content of Lake Michigan water was higher and better; and another thing, that Lake Michigan water is low in organic matter, whereas some of these rivers have considerable organic matter.

Q. What I am trying to get at is whether in coming to a conclusion as to a rate per thousand, experience in other localities was not taken into consideration?

A. Well, I presume they did take it into consideration Mr. Hopkins.

Q. Wasn't that the basis of the whole thing, in the beginning?

A. No, not exactly. It must have been experience at other places, but my recollection is that they carried on some experiments here also.

Q. Do you know just what was done in those experiments? When were they, first?

A. A Doctor J. H. Rauch, concluded, after some studies made by himself, that 180 cubic feet per minute that is 3 cubic feet per second per thousand population, in winter, would be ample. Then there was in 1887 some knowledge of the Blackstone River obtained, and they thought even a smaller dilution than that per second might do.

In Paris, at that time, they knew that 60 cubic feet per thousand people produced inoffensive conditions 14 miles below Paris in the Seine, but they excluded all excrement, fecal matter. But my recollection is that there were some experiments made here, on or about that time, in the old canal, which helped them to arrive at this figure.

Q. How did you compute or estimate this 300,000 floating population?

A. We got such available data as we could from the rail-

roads and the steamship lines, as to the number of passengers, number of people that were brought into Chicago during the course of the year; and as near as we could get at it, there were at this time about 68,000,000. And from that we estimated that by the time 1920 was reached, there would be a floating population pretty close to 300,000 per day. I believe we did count, for a while, passengers coming in at certain stations, to check up on the estimates as near as we could.

Q. Did you make any estimates as to how many were going out?

A. Our total figures showed that at this time there were about 69,800,000 people that came in, through and suburban. The number that left the city, we did not take into consideration, as it was not believed that they amounted to a very large percentage of this number.

Q. Then we would soon have a rather large city here, wouldn't we, if only a very small proportion of those that come in go out?

A. I thought you referred to the people living within the city that went away from here, as an offset to those that come in. Of course the suburban traffic goes in and out practically every day, Sundays excluded.

Q. What was the basis of that sixty-eight or 69,000,000 people?

A. That was the number of people that come into the city on an average, in and out of the city each day; that is 68,000,000 during the year come in, and that 68,000,000 go out at this time, or, to be exact, 69,800,000.

Q. Now did you determine where they came from?

A. No, it is impossible to find that out.

Q. Did you ascertain what part of those people came from within the District?

A. Only as far as we could, but it would only be a matter of estimate, Mr. Hopkins. The error might be in either direction.

Q. You consider, I believe you just said, there is about sixty-eight or 69,000,000 people coming in and sixty-eight or nine million going out?

A. Yes, sir.

Q. Then how did you get the 300,000 here all the time, do you figure that 69,000,000 in a year are in Chicago all the time, and just divide by 365 or 330?

A. The only way we could get at that is they even up. Take the through passengers that come in, they might stay

a day or twelve hours or a week, and as near as we could tell after careful study, we thought the floating population would be 300,000 by 1920.

Q. But you do not take into consideration the people in Chicago that are out of the city?

A. That would be a small percentage of the total.

Q. Nor did you take into consideration, as you say, those that come from somewhere within the District?

A. We could not always separate them. We did it as well as we could.

Q. Isn't it necessarily the case that about as many people are going out as are coming in?

A. That is true that there are as many people going away from a city as are coming in, when you take into consideration the people living in the Suburbs, they go out and they come back, or rather they come in and go back to their homes. The through passengers stop, and go on; but it is not true that as many people go out of a large city and stay away as long as the people that come to a large city.

For instance there are more people that go to New York City and stay there than there are New Yorkers that go out of New York City by a large number.

Q. How did you get this 300,000?

A. That was merely an estimate based on what would be the condition by the year 1920.

Q. I want to get your method of estimation, how you get that result?

A. At the present time, as near as we could tell there are about 69 to 70,000,000 people in a year.

Q. How would vou get the day, so many per day?

A. That gave you so many per day for 300 and some odd days a year.

Q. Then you just divide by 300?

A. No, that would not give it, but we estimated on the growth of the city and the growth in the passenger traffic.

Q. I mean today, how would you determine this same figure corresponding to 300,000 for 1920?

A. Divide by about 310.

Q. Divide 69,000,000 by 310?

A. 69,800,000 by 310.

Q. Why do you select 310?

A. That is practically the year without Sundays; that is the only reason, and ordinarily there are more people in a big city on week days than there are on a Sunday.

Q. As a matter of fact, in the year around, there is quite an exodus on Sundays?

A. I suppose so, but it would be safe if you take the week day conditions.

Q. In the summer time, there are a great many people who leave the city?

A. On Sundays, probably, over Sunday.

Q. Every day, a great many people are out of town in the summer time, in the warm weather, aren't they?

A. Yes, there are quite a number out of town; quite a number in the city, too.

Q. A great many people coming in from day to day are people living in the city, who are returning home?

A. Pardon me?

Q. A great many millions of people coming into the city are people who live here and are returning home?

A. If they lived here, they would not be returning home.

Q. Traveling men who may be out, coming in from time to time. You got your records, I understand, from the railroads?

A. There may be a percentage of those that are counted in twice, but that is on the side of safety, rather.

Q. You have not given consideration to those who lived in the city returning home, those who live somewhere else in the District coming to Chicago, nor the people in the city who are away, in computing this figure?

A. As near as we could we deducted those who lived in the Sanitary District, in the suburbs.

Q. You said you had no way of determining that?

A. Accurately, no. It was a matter of judgment.

Q. You gave no consideration to the other items I called your attention to?

A. It would be a very small percentage of the gross total.

Q. That is the people who live in Chicago and are out are a very small proportion of those that come in every day on those trains?

A. On the average, yes.

Q. So small you didn't even consider it?

A. It would be all on the side of safety to get good conditions here, but as near as we could, we got this up as accurately as we knew how.

Q. As a matter of fact, in every city where they have sewage problems, and in which it has been used in whole or in

part, as a basis of getting at this figure of 3½, there is more or less of a floating population?

A. I do not think the floating population was as great 25 years ago as it is today in the large cities; but as far as the figure of 3½ is concerned, our own experiments and experience here show that is about the proper figure, with trade wastes kept out.

Mr. Hopkins: I move the latter part of the answer be stricken out as not responsive.

Q. (Question read to witness.)

The Witness: I answered it.

Mr. Hopkins: You said 25 years ago something happened.

A. It was not as carefully studied, and I do not believe at that time they took it into consideration. I don't know as that was ever done; and I do not think it was ever carefully studied before the Sanitary District got to studying its own conditions; there was not very good available data as to what was needed for dilution purposes.

Mr. Hopkins: I would like to have the question answered.

Q. In nearly all of the centers where there is a sewage problem, there is a floating population, isn't there?

A. Yes, that is true.

Q. And any tests that might be made down the river from some city as to the condition of the water there would include whatever sewage would come from the floating population wouldn't it?

A. I don't know of any place where they have ever made that study except here, Mr. Hopkins.

Q. The Blackstone River, you mentioned a while ago?

A. The Blackstone River.

Q. Mr. Hering made certain statements, did you hear them?

A. That was back in 1889, and that is hardly a large city.

Q. (Question read as follows): And any tests that might be made down the river from some city as to the condition of the water there would include whatever sewage would come from the floating population, wouldn't it?

A. If any such tests were made, it would include the sewage coming from the floating population, but I know of no such test ever having been made.

Q. You have formed your opinion in regard to the amount necessary based upon the conditions in the Chicago Canal that you have studied?

A. Yes, sir. I did not know anything about the conditions in 1889 myself. I was not even here.

Q. You have some kind of an opinion now in regard to the matter?

A. Yes, sir.

Q. It has been formed on that basis?

A. Formed on the basis of our own particular studies here.

Q. And the condition of the water in the canal as you studied it had in it the sewage from whatever floating population there might be in the city of Chicago, didn't it?

A. Yes, sir.

Q. So that in forming your unit per thousand, all the way through, it was based upon the population of a particular district rather than upon individuals actually sewering into the stream at the time?

A. No, it was based upon, as near as I could tell, the number of people sewering into the canal.

Q. On page 2072 of your testimony, do your figures include any floating population?

A. No, those do not include any floating population.

Q. The state law makes no provision for anything more than the population does it?

A. That I suppose would be a matter of argument as to whether it should, whether it would mean the people that are in Chicago or not. We have assumed that we were complying with the state law if we sent down as much as the population exclusive of the floating population would require, but to be safe and have the proper dilution, I think we should have water enough to take care of the floating population as well as the resident population, and at the rate of 3⅓ cubic feet per thousand people sewering into the canal, whether they be resident or floating.

Q. When did you change your ideas to the extent you thought you had to make an extra allowance for floating population?

A. I don't know as I have changed it.

Q. You said you thought you were doing it properly heretofore, by simply having sufficient water in proportion to the actual population?

A. That was to comply with the state statutes.

Q. And that included trade wastes and everything, didn't it?

A. Yes. Trade wastes have been going in, but the point

remains that we find local nuisances along the canal and the water itself in the canal, the oxygen in the water has been entirely used up before the end of the canal was reached.

Q. Do you have any other basis for your estimate that there will be 300,000 more people in Chicago each day than there are people normally here that are away in 1920, than just some information you have gotten of people coming in on the railroads?

A. Why the only other information I have is such articles as I read; and I read one here a short time ago. As I remember, the estimate compared very closely with the one that I had as to the floating population.

Q. Just what did it purport to give, did it purport to give the population in excess of those that are out of town?

A. As I understood it, yes.

Q. But still your railroad reports show about the same number going out as coming in?

A. Those that come in do go out. They do not come here and stay.

Q. What was this article?

A. I was trying to recollect. It was something I saw recently, and I don't remember where.

Q. Mr. Wisner, what advances in the art of sanitation or disposal of sewage have taken place since October 12, 1911?

A. I think we have found out the difficulties rather than have made any particular advance or change in methods. It has been deemed advisable in certain cases that aeration, for instance, should be used in connection with long sewers to prevent septic conditions in the sewers themselves; and that certain sterilization should be added in connection with plants where the effluent is to go into streams that may get to the source of your water supply. As far as any changes or improvements being made in the way of disposal of the sewage itself, I do not think there has been many; it has been more detail. We have appreciated the care that was necessary to properly handle sewage, to prevent obnoxious conditions arising.

Q. Anything else that you think of that would make the conditions different today from what they were at the time I just mentioned, aside from this matter of aeration and sterilization?

A. There is one other matter that, for instance, was not considered in that report that I made at that time, and that

was the amount of land that it is necessary to have around a sewage disposal station, so that the municipality would control the land and there would not be residences near the sewage disposal station.

At this time, I think there should be at least a quarter of a mile all around a sewage disposal station, and even more than that to avoid future litigation, and local nuisances on property not controlled by the municipality.

Q. You have doubled your estimate on that then?

A. On the amount of land necessary?

Q. On the distance that it would be noticeable?

A. Well, it would depend altogether on the condition of the atmosphere and the wind, as to how far it would be noticeable. I have no doubt that with a foggy saturated atmosphere, and a wind blowing from the Southwest that it might be noticeable two or three miles away at certain times. I know we get odors that far from the stock yards district.

Q. Anything else that you have in mind now that was not considered then?

A. There may be something else. That generally is it, as I remember .

Q. If there are any other matters, are they very important ones?

A. They might be. I do not think of them right now, except there is one other matter, that sites that were available at that time for sewage disposal works are not now available, and the sewage in one particular case would have to be taken a longer distance than we counted upon at that time. The centers of population, or growth of suburbs of the city has changed somewhat from what it was at that time. Districts at that time that were not built up are now building up, and it would make it impossible to locate sewage disposal stations where we thought at that time they could be located.

Q. What has occurred to change your opinion in this: "That it will be impossible to get a continuous flow of 10,000 cubic feet per second through the main channel until the Calumet-Sag Channel is completed"?

A. Well, at that time the Main Drainage Channel had not been widened to its full capacity at this end of the canal; and at the present time that has been pretty near finished.

Q. Was that the impossibility you had in mind?

A. That is the only one I think of now.

Q. You prepared with Mr. Fuller the estimates that he gave, didn't you, in regard to projects of sewage disposal?

A. I went over them with him generally, yes.

Q. The results that you have given in your direct testimony are about the same as his, aren't they?

A. They do not vary so very much. I think there is some variation.

Q. What, generally, is the variation?

A. I do not remember.

Q. Are yours more or less than his?

A. My recollection is they are a little less, slightly less.

Q. You think that one of the principal things to be remedied or prevented, as the case may be, in the canal, is to keep out sewage mud or stale sewage, deposits of that kind?

A. Well, the deposit of fresh sewage mud is objectionable, yes, sir.

Q. Because it would prevent local nuisance?

A. It does, until it has a chance to be what we call worked over or oxidized. After a time it becomes inert and it ceases to give off gases as it does when freshly deposited.

Q. If all the sewage in Chicago were screened and settled, wouldn't most of that be prevented?

A. Most of what?

Q. The sludge deposits?

A. I do not think there are any deposits to speak of at this particular time. I think that with our present flow that there will not be any deposits to speak of. By that I mean that the channel has been so filled up that there is now practically a scouring velocity through it which carries the suspended matter through.

In answer more directly to your question, if all the suspended matter were screened or settled out of the sewage, it would materially lessen the deposits in the channel.

Q. Wouldn't you think with 4,167 cubic feet, this settling would prevent most of the deposits?

A. No, there would be great quantities come in from Lake Michigan every time there was a storm and the water became turbid and muddy, such as we have had here recently. There would be large quantities of sediment that would come into the channel and settle.

Q. That would be dirt and sand?

A. It would be dirt and sand, yes.

Q. That would not be sewage?

A. It would so shoal up the channel that at times, if we wanted, could flow more than 4,167 cubic feet through it,

should desire to do so, it would be impossible to get it through.

Q. That would materially improve conditions over what they would be if you didn't settle it or screen it?

A. As far as nuisances are concerned at the start, yes, sir, but there would come a time when the stream would just take this amount and there would probably be no further settling.

Mr. Adcock: Q. You would reach a scouring velocity?

A. You would reach a velocity such that by the channel filling up there would be no more settling.

Mr. Hopkins: Q. Do you agree with Mr. Hering when he says that by settling the sewage he thinks that 10,000 cubic feet per second would take care of about 4,200,000 people?

A. Just settling it? No, I should say not. In answer to that, I do not agree with him, if he says 4,200,000 people. I think that is too many. As near as we can tell the improvement from screening and sedimentation would only amount to about 25 per cent.

Mr. Adcock: That is the maximum?

A. I think it would be about 25 per cent.

Mr. Hopkins: Q. What percentage of the organic matter would be settled out of the sewage?

A. I think about 25 per cent.

Q. Of the coarser particles?

A. No, I mean of the organic matter in the sewage.

Q. That 25 per cent. would largely be made up of the heavier and coarser particles?

A. It would be made up of that.

Q. As a matter of fact, do not the larger particles require more oxygen to decompose them than the smaller particles?

A. I don't think so. The action is put off longer.

Q. And that would to a great extent remedy the sludge deposits, if that is the part that would probably settle anyway, would settle in those tanks?

A. It would not remedy it, because they are already there, at the present time, in the canal.

Q. That that is already there could be cleaned out?

A. Well then there would be deposits, there would be fresh deposits which to my mind are more harmful than the old deposits which have been partly oxidized.

Q. That is even with this 25 per cent, of the entire organic matter, composed of the larger particles, if that were taken out, still your sewage deposits would be as fast or faster than they were before?

A. Oh, no, I misunderstood you if I said that. What I meant to say was that if we take out the deposits that are in there and then allow the sewage to go in as it is, there would be fresh deposits in the places where we took the old sludge out.

Q. But not so much as there would be without that settling process?

A. If you have the settling tanks in connection with that, there would not be so much.

Q. This was all on the assumption that you had settling tanks for the raw sewage?

A. I misunderstood your question. If you will start in again, I will try and get it right.

Q. Suppose you had grit chambers, settling tanks and screening, wouldn't that decrease very materially sludge deposits in the canal below that?

A. I don't think at the present time that there are any sludge deposits in the canal being freshly made or freshly deposited; I think that the matter is carried through the canal.

Q. Given the same amount of water, if your sewage is treated by grit chambers, settling tanks and screens, wouldn't the sludge deposits be much less than they would without such treatment?

A. Not much, under the present condition of the canal. If, Mr. Hopkins, you remove the sludge deposits that are there now, then the deposits would be much less if they were taken out in tanks and by other methods than they would be if they were not, but the canal now is in such shape that it practically has a carrying velocity throughout its entire length, and the material is not settling in the channel.

Q. As I understand, if you take out the sludge deposits that are now there, there will be a greater tendency to have deposits?

A. Yes, that would make the cross-section larger and the current slower, and it would drop these heavier deposits of suspended matter which are now carried on by the velocity in the channel.

Q. Then it would be better just to leave the sludge deposits as they are?

A. Right at the present time, I think it would be.

Q. And then if you took out this proportion that you speak of by these processes of settling, you would greatly minimize the chance of increasing those sludge deposits?

A. I do not think they will increase under the present conditions.

Q. Suppose your flow of water were reduced to 4,167 cubic feet per second?

A. Then they would increase.

Q. Your sludge would increase?

A. Your sludge deposits would then increase.

Q. Then what effect would settling tanks have?

A. They would tend to decrease it.

Q. By a greater proportion than 25 per cent., too, wouldn't they?

A. They would decrease the sludge deposits by more than 25 per cent.

Q. They would practically eliminate it?

A. There would still be some deposits coming from the sewers and the tanks and also considerable from Lake Michigan water itself.

Q. But that is the only possibly thing to remedy that situation?

A. That would prevent the nuisance in the canal, and tend to purify the sewage.

Q. Now, suppose that trade wastes from tanneries, stockyards and commercial works were kept out, to what extent would that improve the conditions in the canal, or what effect would it have upon the requirements of water?

A. Well, keeping out these manufacturing trade wastes would mean that you would not require as much water to dilute the sewage coming from the city as is required at the present time, when we are not getting sufficient. As stated in my direct examination, I believe that then 3⅓ cubic feet per second would be sufficient to properly dilute the sewage coming from the rest of the city. Of course, a great big city like this, it is almost impossible from a practical standpoint to entirely eliminate all trade wastes.

Q. But you could eliminate a good part of them, couldn't you?

A. You could probably eliminate the worst offenders.

Q. In the estimate as put in by Mr. Fuller, did he include settling of the sewage from the loop district and the West Side?

A. Yes, sir; I think he did.

Q. On the basis of 3⅓ cubic feet of water per second per thousand population, if the sewage were first setled, then 4,167 cubic feet would take care of about 1,600,000 people, wouldn't it?

A. It might take care of 1,562,000, providing that the sewage of the entire population within the district was settled, and that the manufacturing wastes were kept out.

Q. The 3⅓ feet, as now provided by state law, makes no provision for trade wastes and things of that kind, does it?

A. That I am not sure, Mr. Hopkins, whether that is in the law or whether it is in my own mind as to what people have told me that they had in mind, at the time the law was framed. At that time, it was expected that the trade wastes would to a large extent be kept out.

Q. Do you have any idea as to the amount of the coarser, larger wastes that are being deposited in the canal?

A. At the time I made that other report in 1911, we had some figures upon it that are given in there.

Q. Do you have any more now?

A. We have figures, which I haven't in mind now, as to the amount of settling matter that comes from certain sewage districts and from certain industries, in the form of trade wastes.

Q. If those trade wastes were taken care of in other ways, by the industries themselves, that would increase the power of the water to dilute the sewage very materially, wouldn't it?

A. Well, as I said before, it will require more water to properly dilute the entire sewage coming from the people and from trade wastes than it would if the trade wastes are kept out, but I think it will require 3⅓, as near as I can tell now, to properly dilute the so-called domestic sewage.

Q. You say that you have been taking for some little time now about 3⅓ feet per second per thousand inhabitants, and that you consider that the Sanitary District is in very good shape?

A. No, I didn't say in very good shape, Mr. Hopkins. I said there were at times local nuisances along our channel, at times when the oxygen in the combination of diluting water and sewage is practically used up at this end of the canal, and that septic conditions exist in the channel.

Q. That is largely due to sludge deposits, isn't it?

A. I think it was at one time, but at this time I think it is mostly due to the sewage itself and the burden it is carrying.

Q. Trade wastes have been going into that right along, haven't they?

A. Yes, sir; although the last two years it has been pretty well filled up, as far as it will fill.

Q. What has been filled up?

A. The channel itself at the wide places in it, where the velocity originally was slow.

Q. You said that your water supply was very good in Chicago now?

A. Yes, it is.

Q. You are not having any water flowing into Lake Michigan?

A. No sewage?

Q. Yes?

A. Only such as comes in north of the south line of Evanston, and that that comes in through the Calumet River and the Indiana towns and such as comes from passing vessels.

Q. But through the Chicago River you are not getting any?

A. There has not been any flow of the Chicago River into Lake Michigan in the last two years that I recollect.

Q. So that for all practical purposes, your situation now is really good, isn't it?

A. As far as the drinking water is concerned.

Q. As far as the general health of the community, taking care of the sanitation?

A. That is generally true. There are places in the river and in the canal itself and below the end of the canal where the effluent coming from our works is not what it should be.

Q. Now, as a matter of fact, aren't the trade wastes that get in there a very big item; it takes a great deal of the oxygen?

A. Undoubtedly that is so. It is also true that within the the last two years these larger offenders have improved the condition of the effluent coming from their works, and they are not putting in so much of the solids as they did two or three years ago. But at the same time they are putting a big burden upon the diluting water that we use; and to my mind, if this burden was not there, why the canal and the river below the end of the canal would be in just about such shape as it should be.

Q. Do you have any idea how many people could be taken care of by the water and oxygen which is now necessary to dispose of these trade wastes?

A. That is a rather difficult question to answer.

Q. Could you make any outside limits?

A. It would amount to several thousand people.

Q. Could you give us any figure on that?

A. I would not want to hazard any guess on that.

Q. 500,000?

A. I suppose a man could guess 500,000, but I am not going to.

Q. I believe in your report you said that the remedy for overloading of the sludge can be settled at once, by having all the suspended matter settled out?

A. To what page do you refer, Mr. Hopkins?

Q. Page 22, just before you get to the Ogden Ditch?

A. (Referring to same.) Yes, I said that.

Q. And that settling would probably dispose of the floating matter; certainly screening would, wouldn't it and dispose of the parts that are offensive to the eye?

A. It would probably have to be a combination of screening and settling, and possibly some chemical precipitation of some kind. We are at the present time carrying on experiments to see what we can do with the trade wastes coming from Packingtown and the packing industries, and as yet we have not got the solution.

Q. Don't you think that a combination such as you suggest there would really take out more than 25 per cent. of the organic matter?

A. I doubt it; a little less if anything. That is from the results of our experiments.

Q. Have you experimented with the combinations?

A. Yes, we have experimented with the combination of screening and settling and with different kinds of settling tanks, and are now experimenting with chemical precipitation.

Q. This aeration that you speak of, which is new to you, you simply mean the aeration in the sewers proper; you had in mind the aeration of sewage in general, didn't you?

A. Had in mind the aeration of the sewage proper on the way to the treatment works, to keep it from becoming septic, and causing nuisances en route.

Q. At the time this report was written, you had in mind aeration of the canal?

A. That was in connection with increasing the oxygen in the canal itself, and also the possibility of aerating the effluent of settling tanks.

Q. Wouldn't this aeration of the sewage on its way to its place of treatment tend to increase the oxygen in the fluid itself, and help your dilution process in the long run?

A. It would help out the sewage treatment on disposal works and keep the sewage, as we call it, fresh instead of septic.

Q. If it did not go to settling works, it would help the dilution, wouldn't it?

A. I presume it would, some.

Q. Do you have any reason to change the opinion that you expressed in that report very positively two or three times that the drinking water of Chicago should be filtered?

A. I don't remember that I stated that it should be, absolutely positively. I said, as I recall, that from an aesthetic standpoint that it undoubtedly would be at some time.

Q. I do not find the place in the report, but whatever is in there, you have no occasion to change it, whatever you said in regard to filtering?

A. I could tell you what is in there.

Q. It is not only in the recommendation, but there is another place where you had it positive?

A. I think you are mistaken, Mr. Hopkins, if you think that I urged it in this report.

Q. Whatever is in there you have no occasion to change; nothing has occurred to change it?

Mr. Adcock: You mean as to what?

The Witness: As to the filtration of the water supply. You are only referring to the filtration of the water supply?

Mr. Hopkins: Yes.

The Witness: My recollection is that I said that it was thought in time to come, for aesthetic reasons and other reasons that that it would be urged that the water supply be filtered; and I presume that may come.

Q. Now, in your sprinkling filter system as outlined in that report, in your plans for 1920 and 1930, you were going to put through sprinkling filters the sewage from the North Side, the sewage from the Calumet District, the sewage from the South Side, weren't you?

Mr. Adcock: You refer to the 1911 report?

Mr. Hopkins: Yes.

A. It is all in there, what I had in mind at that time. It is some time since I looked it over carefully. I gave estimates at that time on those projects but my recollection is that the sprinklers were not to be installed until after 1930. I may be mistaken about that. Anyway, the report gives it.

Q. You gave estimates for sprinklers to be installed in 1930?

A. In the Calumet region.

Q. I think in all the regions that I have mentioned?

A. I gave estimates for them, but they were not to be installed as I recall before 1930.

Q. But as far as what you were going to do is concerned, it does not make any difference whether it is 1930 or not?

A. It does as a matter of cost.

Q. You think it will cost more then, don't you?

A. More to install them than than now.

Q. Yes?

A. I think the chances are that they may cost more.

Q. You were going to treat by sprinkling filters the sewage from the districts I have named, weren't you, in 1930?

A. I think it was after 1930.

Q. Well, after 1930?

A. That is providing that the district was limited to 10,000 cubic feet per second.

Q. Then your estimates were based upon that?

A. Upon those districts.

Q. Upon treatment by a sprinkling filter?

A. Of the excess population over and above 3,000,000, which was not offset by sedimentation.

Q. Don't you in your report provide for the treatment by sprinkling filters of all the sewage from the districts that I have named?

A. From certain districts; whether that was the districts you have named or not, I do not at this time recall.

Q. Do you have the report referred to before you?

A. Yes, sir.

Q. Will you refer to it and see if you do not include the districts I have named?

A. I gave estimates on several different projects. There were no recommendations as to when they should be built except as to the Calumet District. I did recommend, as I remember, that certain sites be procured so that if in the future it seemed best to treat certain districts, that those sewerage districts could have the sewage treated.

Q. Your estimates, however, were based upon carrying out the sprinkling system process?

A. Wherever used; yes, sir.

Q. Will you refer to page 66 of that report?

A. Yes, sir.

Q. There you give an estimate of treating a certain designated population amounting to about 1,400,000, which includes estimates for both settling and sprinkling, and for the annual cost, doesn't it?

A. Those are three different projects, and it gives the first cost of each of them and the annual cost of each one

of them. It does not anywhere say that they should all be built.

Q. I didn't ask you that. I asked you for the estimate of the cost; if you did not make an estimate of the cost.

A. I said that I made an estimate of the different projects.

Q. The sewage which was to be treated in those estimates is practically the same sewage as is spoken of by Mr. Fuller in his estimate as to what part is going to be treated by sprinkling filters. To refresh your recollection a moment, was not the West Side and the Loop District to be sent down by the dilution process, and the North and South Sides and the Calumet District to be treated by sprinkling filters, in his project?

A. This report was written on the basis that there would be 10,000 cubic feet of water available for dilution; and the Fuller estimate that you speak of is on the basis that there would only be allowed a diversion of 4,167 cubic feet per second.

Mr. Hopkins: I move that the answer be stricken out.

The Witness: And therefore these estimates of Mr. Fuller and those made by myself in 1911, were not on the same basis.

Mr. Hopkins: I move the answer be stricken out as not responsive.

Q. My question is, if the sewage from the population which you estimated the cost of treatment for is not practically the same as the sewage from the population that Fuller had under consideration?

A. No, sir.

Q. Well, you estimated on the treatment of all sewage collected in the Calumet District in that report, didn't you?

A. In the Calumet District it might come near being the same, but the other districts would not.

Q. In that estimate, you had in mind the sewage of all the population which was collected through the intercepting sewers and through the 39th street pumping station, too, didn't you?

A. I had in mind all of the sewage, Mr. Hopkins, but I did not have in mind treating anything except for the excess population over 3,000,000 people.

Q. Isn't this the situation: That you said in that report that with 10,000 cubic feet a second you could take care of 3,000,000 people, but that you thought you ought to have sedimentation anway?

A. In connection with the growing population, I felt that in a city like this, that is growing 50 or 60,000 people per year, that there should always be available surplus works to take care of the people?

Q. Here is my point: That until you exceeded 3,000,000 people, your 10,000 cubic feet would take care of it without sprinkling filters?

A. It would, or without sedimentation tanks; but you cannot build those works in a day and I figured by 1920 that population would be reached, and by the time that we could install works to take care of the excess population after that, in order to take care of the excess population we should start building at once, providing we would be limited to 10,000 cubic feet per second.

Q. I think we can work together better, if you keep in mind that I am not trying to ask you about your recommendations so much as about estimates. You recommended that until the population exceeded 3,000,000 you would not need sprinkling filters?

A. No, you would not need sprinkling filters until it did exceed that.

Q. You made an estimate, however, of what it would cost to run all your sewage of the North Side through settling tanks and through sprinkling filters located in the places mentioned there, didn't you?

A. Not all the sewage, no, sir.

Q. Of the North Side?

A. No, sir; not as I recall it.

Q. You did not say anything about any sewers taking any part of it directly into the Chicago River or the Drainage Canal, did you?

A. There were certain sewers I was not going to touch at all; just let them go on and do as they were doing, and are doing now.

Q. It will not make any difference in the cost of sprinkling filters whether you have 4,167 or 10,000 cubic feet in the river itself, if you put all the sewage through the sprinkling filters, will it?

A. If the same amount of sewage went to the sprinkling filter, I suppose it would cost just the same in either case.

Q. If in fact you did consider in that estimate that all of the sewage of the North Side and of the South Side and of the Calumet District was to be treated by sprinkling filters, has anything occurred to change your estimates, with

the possible exception of this matter of aeration in the sewer proper, and of sterilization?

A. In the first place, I want it distinctly understood that we did not include all of that or have it in mind as being treated. I am perfectly willing to answer your question, which I understand is: Has anything occurred between 1911 and the present time that would tend to make me give higher estimates than I did at that time. That is what you are getting at, isn't it?

Q. Yes?

A. The aeration which you mentioned.

Q. Can you give the amount of that?

A. I think we have got that; I haven't it in mind. I can get that for you; and the sterilization of the effluents, and larger areas are provided for the reason that I have stated, that in this estimate we just gave an estimate of the actual land that is necessary. Since that time I realize that we must control land lying around the filters as there is bound to be some odors come from sprinkling filters.

We have also, since then, prepared detailed plans for a plant of this kind and the figures given in the report of 1911 are lower than they should be. As I stated before, I think at that time I was inclined to give estimates lower than were warranted, by the actual experience that has been had since that time.

Q. Can you tell how much should be added to the estimate by reason of extra land, how much for sterilization, aeration, and then how much in error you were in that estimate generally?

A. I suppose I could by doing a great amount of work to get that out; it would take some time. And as I stated before these two estimates are not comparable. One is based upon a certain flow and the other on an entirely different flow.

There was one thing that I forgot to state, that in the report of 1911, we did not take into account the expense of taking care of the public utilities, which these schemes involve. That is in building big sewers down through the streets of the city, you disturb the water mains, gas mains, electric conduits, telephone conduits, street car tracks, railroad tracks, paving.

Q. Well on project A, as described by Mr. Fuller, the sewage was to be treated under the present combined system of sewers, wasn't it?

A. I have forgotten which project that was. He had one project—

Q. So that in that project you would not have to take up all the streets of the city, would you?

A. Not all of the streets, but you would have to take up the streets along which the intercepting sewer went, Mr. Hopkins?

Q. How many intercepting sewers would be needed for that on project A?

A. Miles of them. I could have the list scaled off of the plans, giving you the distances that they travel through these streets, if it is desirable. I can get that for you. It takes some little time to add up the different lengths.

Q. Did you see what the estimate was in regard to aeration that was to be added?

A. That is given in my direct testimony on page 2095.

Q. Does that include the sterilization there?

A. It also gives the sterilization, it is called disinfection.

Q. Under which head, storm water disinfection or domestic sewage disinfection?

A. Both.

Q. I believe there is included in there the cost of an intercepting sewer in the Calumet District to keep any sewage from going into the Calumet River?

A. That is in there, I think.

Q. Did you say it was included?

A. Yes, that is included in those estimates.

Q. Such intercepting sewers would be necessary in a dilution method, even though you had two or 4,000 cubic feet of water, through the Calumet-Sag Canal, wouldn't they?

A. They might be different in detail, but in our Calumet project that we have estimated the cost of, we have included the cost of those sewers.

Q. In which Calumet project do you estimate that?

A. That is given in my direct testimony as I remember, the cost of the Calumet project.

Mr. Adcock. You mean under the dilution method?

A. Under the dilution method for the Calumet channel.

Mr. Hopkins: Q. So that that expense would be the same under either theory, whether you got the water or not?

A. It would be a little different, but in comparing the estimates they have been included in both cases.

Q. I believe you say the sewer system in the Loop ought to be remodeled throughout, regardless of whether the dilution method is used or not?

A. I think that is true. It has not been included in any of these estimates, however.

Mr. Adcock: Q. That is, it does not make up a part of the cost of any of the different projects?

A. No, sir.

Mr. Hopkins: Q. What is your income or would be your income a year from the sale of power; what is your annual income from the sale of power?

A. Now?

Q. Yes?

A. I don't know what it is now.

Q. Do you know what it would be if you were limited to 4,167 cubic feet per second?

A. It would depend on how it was disposed of.

Q. It would be a credit, whether you used it or sold it, wouldn't it?

A. What I mean by that is that we sell it to the City of Chicago for one price, practically cost. We sell it to commercial consumers at as near the market price as we can get. The people are receiving the benefit in the form of cheaper lighting.

Q. You have no other source of income except taxes, besides the water power?

A. Some leased property, and we have given credit for that.

Q. That is nominal?

A. It is given in the testimony here; I think about $80,000 a year. And of course interest on deposits and things of that kind, merely incidentals.

Q. Your main source of income to take care of operating expenses of any of the projects that you have mentioned would be taxes, wouldn't it?

A. Yes, sir; that is the main source of income.

Q. Annual taxes?

A. Yes, sir.

Q. You are familiar with the applications that have been made to the Secretary of War for permission to divert water from time to time, weren't you?

A. Some of them. I have been somewhat familiar with all of them?

Q. You knew that you were limited, and have been limited for about ten years now, to 250,000 cubic feet?

A. As it affected the navigation of the South Branch; I have always considered that that was the cause of the limitation put upon us.

Q. You knew that an application was made in 1906 in con-

nection with the Calumet-Sag Canal to Secretary of War Taft and denied?

A. For an additional 4,000 from the 10,000.

Q. You knew that?

A. I knew that such an application had been made.

Q. You knew an application was made in 1907 in regard to the diversion of water through the North Shore Canal at Wilmette, that was granted on condition that the total diversion from Lake Michigan should not exceed 250,000 cubic feet a minute, already permitted?

A. That diversion also went through the South Branch, so the current—

Mr. Adcock: You could not increase it.

Mr. Hopkins: You knew about that permit?

A. I don't remember that particular one. I knew there was some permit, Mr. Hopkins.

Q. You knew you were never given permission to take more than that amount in the last ten years, 250,000 cubic feet a minute at any place?

A. I don't know that we ever had any positive permit to take more than 250,000 in the last seven or eight years.

Q. You knew you made application to the Secretary of War in 1910, to dig the Calumet-Sag Canal and got permission on condition that the total diversion should not exceed 250,000 cubic feet a minute?

A. I don't remember whether that was specifically put in, 250,000 cubic feet per minute, or not. I know the sense of the permit was that we could not—we had not a permit to withdraw more through both channels than we would be allowed to draw through the Chicago River.

Q. And that was at that time limited to 250,000 cubic feet a minute?

A. Based upon not creating a current to exceed a mile and a quarter an hour.

Q. Regardless of what it was based upon, that was the amount it was limited to.

Mr. Adcock: I object to that.

A. I don't remember whether it was changed at all.

Mr. Adcock: I object to that; that is a matter of record and the permits themselves show.

Mr. Hopkins: I am asking for his knowledge of the limitations.

Mr. Adcock: I do not see how that is material.

Mr. Hopkins: Q. As a matter of fact you were familiar with all of the permits?

A. I have read them all.

Q. And applications?

A. I have read them all. I could not tell you now what was in all of them. I know that we were limited on account of the small size of the South Branch, so as not to create a current in excess of a mile and a quarter an hour.

Q. As a matter of fact, Mr. Wisner, in the offices of the Sanitary District, you do not use as drinking water the local lake water?

A. No, for the simple reason that all of these buildings store their water in tanks on top and the water becomes unfit to drink. It has to be pumped and put in tanks on top of the building, and soot and dirt get into it.

Q. Then a large part of the drinking water throughout the city is subject to the same condition?

A. In the business district, the water supply would not reach these floors we are on; there is not sufficient pressure. Whether they drink it in the basement or not, I don't know. I presume they do. They serve it in the restaurants and in cafes.

Q. In your Exhibit 6, you have put in a chart showing the levels of the lakes before and after the opening of the canal. Do you think that the higher elevation sometime after the canal was opened compared with 1896, is due to the opening of the Drainage Canal?

A. I don't know what it is due to entirely. I know it exists. That is taken from the record of the U. S. Lake Survey.

Q. You do not mean to intimate anything by that as to the cause of that elevation?

A. I did not say anything about the cause of it.

Mr. Adcock: It is just a fact, a physical condition.

The Witness: It is just a fact.

Mr. Hopkins: I move it be stricken out then.

Q. If you had completed your average down to 1912 or 1913, there would not be as great discrepancies as shown there, would there?

A. Well, we simply took it up to the time this suit was started, and for the same number of years before.

Q. The time this suit was started; it was started in 1908, wasn't it?

A. I thought it was 1910. I know we had the records at that time.

Q. Have you made a computation of lake levels including 13 years after 1900, and the 13 years before?

A. No, for the reason that the 13 years before was when they were, as I recall now, was about the time they were making changes in the Detroit River, which to my mind had some effect upon the levels of Lakes Michigan and Huron.

Q. In other words that would have shown the average was higher before—

A. Before the government made these improvements.

Q. —before 1900 and was lower after 1900, and tended to equalize the levels?

A. I don't know as it would. It might have tended to bring them closer together; I don't know. I have not made that computation.

Q. You can tell it was a good deal lower, the average, in 1912 and 1913?

A. It was lower in 1911, but not as low as it was in 1895.

Re-direct Examination by Mr. Adcock.

Q. You have had some experience, as I understand it, Mr. Wisner, in the operation of this channel?

A. Yes, sir.

Q. You have had occasion to observe the conditions of flow with reference to whether or not the ratio of dilution that is provided for under the state law is approximately the correct ratio, when you take into consideration the condition of the lake water and the sewage here, domestic sewage?

A. I think it is, with the trade wastes removed.

Q. Your experience has run over several years, as I understand it?

A. Yes, sir, and within the last year the experiments that we have made tend to show that on certain days, like Mondays for instance, when there are not such excessive amounts of trade wastes coming from the industries such as the tanneries and the packing houses, that then the dilution is almost sufficient, whereas on week days when there are large quantities of these trade wastes going in, it is not sufficient.

Q. Then you have reached the conclusion from experience, practical operation of the canal and from the experiments which you have made, that the legal ratio of dilution is practically correct for the domestic sewage?

A. That is my opinion at this time, as near as it is possible to tell, that that dilution is sufficient for the domestic sewage.

Q. Now you were asked on cross-examination about lowering the dam at Lockport, the opening, so as to take care of a flood condition, on the assumption that the flow of water through the channel from the lake was limited to 4,167 cubic feet per second. In that connection, I would like to ask you whether or not if the flow were limited to that amount, the channel would after some years of operation tend to fill up, so that it would have a capacity of approximately that amount?

A. It would not only tend to fill up, but it would fill up so that it would in time have a capacity of practically that amount only.

Q. What effect would that condition have upon the opening of the gates, opening of the dam at Lockport, to take care of flood conditions?

A. It would mean that we would be unable to take care of the flood conditions, and practically all water, storm run-off, in excess of 4,167 cubic feet per second, would be discharged into Lake Michigan polluting the water supply.

Q. In the earlier years of the operation of this channel, as I understand you, there was less water flowing through it than there is now, is that correct?

A. Yes, sir.

Q. As a result of that condition, was there a tendency to deposit sludge matter greater than there is at the present time when the flow is approaching more the capacity of the channel?

A. Very much greater, and the deposits did take place.

Q. So that now there has been deposits sufficient to fill up the channel at certain points, so that there is a continuous channel with a scouring velocity, and there are no deposits being made.

A. In my opinion there are practically no deposits being made in the main channel at the present time.

Q. You have been asked about your understanding with reference to the permits. Did you ever have any talks with government officials about the amount of flow of water through the Sanitary District Channel from time to time, during the last period of years?

A. Yes, sir.

Mr. Hopkins: First, I think we ought to know what government officials he has talked with, and whether they were speaking in an official capacity.

Mr. Adcock: Whom did you talk with?

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A. I talked with members of the International Waterways Commission, including my father, Mr. Haskell, General Ernst, who had at one time or another been members of this Commission; also with Mr. Gardner S. Williams.

I talked with General Bixby, while he was engineer officer in charge of the Chicago District; also talked with him when he was in charge of the St. Louis office, just prior to the time that he was made Chief of Engineers, and innumerable times with him while he was Chief of Engineers; also with Colonel Zinn, who was in charge of this District; Major Riche and, there was another officer here just before Colonel Zinn came; I do not recollect his name now. And in Washington I talked with Colonel Taylor, Burr; I don't remember their exact titles, and several others there that I have forgotten the names of. General Marshall, I believe I have talked with him about it too.

Q. As I understand it, the Sanitary District first commenced to improve the Chicago River in 1896 or '97 was it not?

A. That was the dredging, yes, sir.

Q. And as you stated before, the purpose of that improvement was to furnish a greater cross-section, to flow a greater amount of water through the channel?

A. For the purpose of furnishing a larger cross-section and keeping the current down to a mile and a quarter an hour with the increased flow going through the South Branch of the river.

Q. In 1896; that was known as the first project, was it not?

A. Yes, sir.

Q. Then there was another project that was entered upon along in 1900, was there not?

A. Yes, sir.

Q. That contemplated a wider river and a deeper channel than the first project?

A. Yes, sir.

Q. During the time that the channel has been in operation, you have actually flowed more water than 4,167 cubic feet per second, have you not, during the greater portion of the time?

A. During the greater portion of the time, that is true.

Q. In your talks with General Bixby, when he was here, and while he was Chief of Engineers, did you inform him as to the amount of water that the District was flowing?

A. Several times I told him, not only when he was here but when he was in Washington, the amount of water that we were flowing; and also have told the Government Engineers that were stationed here.

Q. The project providing for the improvement of the Chicago River and the South Branch of the Chicago River is practically completed?

A. It is.

Q. Except in some small stretches?

A. Some small stretches.

Q. When the improvement is completed, as provided for, will the river accommodate a flow of at least 8,000 cubic feet of water per second, without injury to navigation?

A. There is no doubt in my mind that it will, for the reason that at times we do flow that through there at the present time, and we have no complaints from the navigation interests in regard to the current. That has been so in the last two years. The only complaint that I remember of in the last several years was one that was caused by the construction of the Pennsylvania bridge across the South Branch at Stewart avenue, where, in putting in the foundations, it became necessary to clog up a part of the river with cofferdams.

Mr. Adcock: That is all.

Re-cross Examination by Mr. Hopkins.

Q. You mean that there has been no complaint made to you?

A. Well, in the old days, I used to get them often, Mr. Hopkins, and lately there have not been any complaints made about this condition.

Q. There were complaints made to the Secretary of War, when you made your last petition, weren't there, your last application?

A. By only one man and he referred particularly to the case that I mentioned, the condition at Stewart avenue during the reconstruction of that bridge.

Q. As a matter of fact, aren't all the navigation interests opposing, and complaining that the rate of flow is interfering with navigation?

A. I have not had any complaints in the last two years.

Q. In talking with all of these men that you have men-

tioned, didn't you know what the government limitation was in cubic feet per second?

A. I knew it was the limitation in regard to the mile and a quarter an hour. I also knew, Mr. Hopkins, that at the time that was made that 250,000 cubic feet per minute was all that could be gotten through the Chicago River at certain places without creating a current greater than a mile and a quarter an hour.

Q. But there had been several applications in recent years, and they were always refused, unless no more water were taken?

A. Only as I understand it in regard to a flow of over 4,000 additional to the 10,000. The one in regard to the North Shore Channel, any diversion that was made through there the water had to pass through the South Branch the same as though it had come in through the main river.

Q. You were familiar with what applications and what permits there were?

A. I have seen them, yes, sir.

Q. Talking about this question of the storm water again, do you mean to say that if you were given permission to increase the flow at Lockport, in order to prevent storm overflows going into the lake, you could not do so to such a degree that the amount that would get into Lake Michigan would be practically unnoticeable?

A. What is that?

Q. If you were given permission to increase the flow at Lockport, to prevent overflows into Lake Michigan, couldn't you do so?

A. I do not think it could be done, Mr. Hopkins, providing that at other times we were held strictly to a flow of only 4,167 cubic feet per second, for the reason as stated that the Main Channel would then on account of the slow velocity of the current deposit material on the bottom of the channel decreasing the cross-section to such an extent that the channel would not carry much in excess of 4,167 cubic feet when you wished to use it. That would not occur immediately, but in the course of time.

Q. How long would it take it to fill up, take the canal to fill up in such a way it would interfere with the flow?

A. Just giving you my best judgment, I imagine inside of three or four years.

Q. That could be dredged out?

A. That could be dredged out at great expense, and there

is no place that I know of where it could be placed without great danger to the water supply, or great expense.

Q. How many cubic yards do you think that would be?

A. Well, I would hate to guess on that. That is a matter of computation which you could have figured out for you. I have not figured it.

Q. What do you think the depth of the fill would be?

A. I do not know. I know that in some parts of the channel there were fills of 12 or 15 feet.

Q. Wouldn't those fills come at certain places rather than tend to scatter out?

A. They would come where the current velocity was such that it would deposit the suspended matter.

Q. So that it would be much easier to dredge it than if scattered out?

A. Oh, no, I think it would be generally scattered throughout the entire length of the channel, with a flow of only that amount.

Q. Where does this sediment come from?

A. It comes from Lake Michigan and also from the sewers and from street washings that flush into the river, snows, and it is impossible to keep the solid material out of the river. Take this last storm for instance, there were large quantities of sediment, of water that we pump through 39th Street Station, through the 39th street conduit, bringing a large quantity of cinders and sand into the South Fork, and we have already had to dredge it out twice, and it was not all sewage mud. It was a large percentage stuff that came through in suspension from the 39th street pumping station; and we are now figuring upon enlarging that so as to avoid that to some degree if we can.

Q. And a large part of it comes from Lake Michigan?

A. A large part of it comes from Lake Michigan.

Q. If the sewage were settled in the way we have discussed before, you would take out a large part coming from the sewage, wouldn't you?

A. You would take out a large part coming from the sewage, that would be true.

Q. If you had 10,000 cubic feet instead of 4,167, you would have a great deal more coming in from Lake Michigan?

A. No, sir, that would go through.

Q. Where would it finally stop?

A. Well, now that is pretty hard to tell. It might be the Gulf of Mexico.

Q. You think the difference in current between 10,000 and the 4,167 would be sufficient to put it to the Gulf of Mexico?

A. That is not the point. It would probably be carried down into the Illinois and Mississippi Rivers, which in times of flood have great scouring velocity, and scour the material on down and it is carried out and that is undoubtedly what is forming deltas at the mouth of the Mississippi River. Of course all of that material does not come from us, but some of it probably does.

Q. With the screening, and authority under emergency conditions to send 10,000 cubic feet through, you could practically keep it cleaned out, couldn't you?

A. I don't think so. It would take some time to scour that out and we would not do it in a short space of time, and by the time we got it scoured out the damage would be done by the Chicago River reversing itself and flowing into Lake Michigan.

Q. How many days in the year does Lake Michigan carry any great proportion of sediment?

A. This last year, I presume in the last 60 days there has not been a day but what it has carried considerable.

Q. Hasn't that been very unusual?

A. I will say it is as bad as I have been it for some time, but there is never a year goes by but there are several days when the water of Lake Michigan is turbid and carries a large amount of suspended matter.

Q. If at such time your rate of flow through the river were increased to meet that emergency situation, you would not get much of a deposit, would you?

A. Well, if we could flow 10,000 cubic feet all the while, I do not think we would.

Q. All the while, for those few days of extraordinary—

A. It is not a few days; it is a great number of days during the year in which the water in Lake Michigan is turbid and carries considerable suspended matter.

Q. Assuming you keep your canal cleaned out in any way you see fit; you say that nine hours is the maximum time for the effect to get back?

A. No, I didn't say maximum; I said as near as I could tell nine hours was about the time that it took for the effect to be felt up here.

Q. You said from six to nine?

A. I was trying to be liberal on that. As near as I can

tell it is from six to nine hours; about seven to nine hours I think I said.

Q. What would you say would be the average time that water falling from rainfall would get into the canal?

A. It would depend on how fast it fell and how close it was to the river and how close along the river it was to the canal.

We had one flood down on Hickory Creek, which is a creek that comes into the Desplaines River at Joliet, in which they had a severe rainstorm one night; I think it started in about eleven or twelve o'clock and the next morning a good share of Joliet was submerged. I do not see any reason why the same kind of a storm could not take place on one of the branches of the Chicago River.

Q. That was an exceptional condition, wasn't it?

A. It is not so exceptional. That was as large a one as I knew of, but those conditions happen every few years around here.

Q. How many miles of sewer does the water have to travel through?

A. To get into the river?

Q. Yes?

A. Oh, from nothing to probably eight or ten miles. A great many of the sewers here are comparatively short, because the city is divided up by the river itself and the different canals we have built, so that a good share of it hasn't long distance to travel.

Q. Out of this 6 to 10 days a year in which the flow of the Chicago River would normally exceed 4,167 cubic feet per second, how many do you think would be so quick, and right at the mouth here that you could not take care of it by properly opening up at Lockport?

A. The only thing that I can say is that when we were flowing these smaller amounts there was usually several times, two or three times during the year when we could not keep the water from getting into Lake Michigan.

Q. Were you trying then, very hard?

A. We were trying, yes.

Q. You were lowering it to the extent of 10,000 or 14,000 feet at Lockport, its full capacity?

A. No, we never had it down to 14,000. We had it down to 10,000.

Q. You think you could reduce that now, with more care, to less than two or three days a year?

A. With a flow of only 4,167 feet initially?

Q. Yes, that is what you said you had it.

A. I doubt it. That is eliminating also the other problem that the canal has not so filled up that it would not flow much in excess of that.

Q. What would be the cost of sterilizing the river water for two or three days when the flow might be reversed, two or three days in a year?

A. I have not figured upon that. I do not consider it practicable to sterilize the river water itself.

Q. Wasn't that included in Mr. Fuller's estimate?

A. No, he sterilized the overflow of the sewers, not the river.

Q. Was he going to sterilize it in the sewers?

A. No, the overflow coming after a certain amount was reached, as I recall it at the sewer outlets, the overflow in contact tanks.

Q. Couldn't you still do that?

A. Oh, that can be done, yes.

Q. In that way avoid any unsterilized water going into Lake Michigan?

A. Except such little as might be in the river itself. The river itself is always bound to be more or less polluted.

Q. The amount then of sewage that could get into Lake Michigan would be reduced to an infinitesimal proportion of the total amount of sewage?

A. No, there would still be sewage get in, organic matter, but it would be probably pretty well sterilized.

Q. Storm conditions on the Calumet, even if you have 4,000 cubic feet, there will be a great many more days in the year when you will have sewage flowing into Lake Michigan than in the Chicago River?

A. As I stated, it is our intention to keep the sewage out of the Calumet River as far as the State of Illinois is concerned; and as soon as we get our own back yard cleaned up, we are planning to get our neighbors in Indiana to take care of their sewage, so that in times of excessive floods in the Calumet, the water will not be in the polluted condition it is at present.

Q. The question was that there would be more days in the year when the Calumet River would flow into Lake Michigan than the Chicago River?

A. That is so, but you injected into your question also

that there would be more days when the sewage of the Calumet River would flow into Lake Michigan.

Q. Whatever there was?

A. The sewage would undoubtedly be kept out of the Calumet River.

Q. That is you would hope to have that condition?

A. That is what we will get.

Adjourned subject to notice.

Depositions taken before the Commissioner, at the offices of the Sanitary District, Chicago, pursuant to notice, beginning on Thursday, March 5th, 1914, at 10 o'clock A. M.

Present:

Mr. Edmund D. Adcock and Mr. Alfred S. Austrian, on behalf of the Sanitary District.

Mr. Albert L. Hopkins, on behalf of the Government.

LYMAN E. COOLEY, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?

A. Lyman E. Cooley.

Q. Where do you reside?

A. Evanston, Illinois.

Q. What is your present business?

A. Civil engineer.

Q. You are connected with the Sanitary District as consulting engineer, are you?

A. I am at present consulting engineer of the Sanitary District of Chicago.

Q. How long have you been connected with the Sanitary District in such capacity?

A. I have been connected with the District in that capacity since December, 1912.

Q. Will you state your education and experience, qualifications as civil engineer?

A. I was educated, and received the degree of civil engineer at the Rensselaer Polytechnic Institute, Troy, New York, in 1874, and have practiced my profession ever since.

For the first eleven years from 1874 to 1885, I was con-

nected with the Northwestern University; for $3\frac{1}{2}$ years, as professor of engineering and professor of mathematics.

I was also the associate editor of the Engineering News, when it started in Chicago in 1875, and for three years subsequent thereto, and later was the editor of the American Engineer.

For six years of the time, I was assistant engineer to the War Department on the improvement of western rivers, principally the Missouri River.

For the following ten years, after I returned to Chicago in 1884, my work was largely connected with the development of the Chicago Sanitary District enterprise, and in connection with the Sanitary District.

From 1895 to 1905, I was engaged largely in private practice. I was consulting engineer of the district in 1897.

I was on the Intercepting Sewer Commission which designed the system of intercepting sewers on our lake front, for the City of Chicago in 1896 and '97. And I was the working member of the Commission on a comprehensive plan for the Sanitary District in 1901.

I was on the International Deep Waterways Commission in 1905 to 1907; a member of the American Section, which was known as the U. S. Deep Waterways Commission.

I was engaged in the investigation of the expenditure of $9,000,000 for the enlargement of the Erie Canal in 1908. That was for the State of New York.

I acted as engineer to a group of contractors who visited Panama and Nicaragua, in 1897 and 1898, in the interest of a New York financial group that proposed to finance the building of the Nicaragua Canal, in case this group of contractors would mature plans and make propositions. I spent about a year on that proposition.

I was the engineer of the Union Water Company, or the consulting engineer, rather, at Denver, Colorado, from 1899 to 1904, and in that capacity had general oversight over the construction of the Cheesman Dam, 210 feet high, and at that time the highest structure in the world of that character.

I was also the designing engineer for the Keokuk and Hamilton Waterpower Company that worked out the proposition of Keokuk in 1901, '05, when they procured their enabling act from Congress. That enterprise has since been carried out.

I also was engaged in a number of other enterprises. I reported on four Michigan streams in regard to the water power available in them.

Reported upon the Barge Canal and the flood conditions in the Genesee River at Rochester, New York.

I was employed by the City of Omaha to appraise the waterworks for the city of Omaha. And I had a number of other minor engagements.

After 1905, down to the time of my engagement with the Sanitary District as consulting engineer in December, 1912, I was the secretary and later the consulting engineer of the Internal Improvement Commission of Illinois; wrote the report in 1907, which underlies the constitutional amendment adopted by the people of this state in 1908, providing for the expenditure of $20,000,000 in the development of the Deep Waterway between Lockport and Utica.

Since 1909, I have been consulting engineer of the Lakes to the Gulf Deep Waterway Association, which is interested in developing a deep waterway between the lakes and the Gulf of Mexico.

I was also on a Commission to devise plans for new waterworks for the City of Omaha.

I made an appraisement of the waterworks at Racine, Wisconsin.

I also wrote reports on flood conditions, at Grand Rapids, Michigan, and at Saginaw, Michigan.

I was the leading expert in the State case of the State versus the Economy Light & Power Company from 1907 until 1909; also of the Federal case.

Q. By whom were you employed in those two cases?

A. In the State case, I was employed by the Attorney General of the State of Illinois and in the Federal case I was engaged from 1910, until sometime in 1912, employed by the District Attorney at Chicago.

Q. That is you appeared in behalf of the United States Government in that case?

A. Yes, sir. And a number of minor engagements.

Q. You were connected, were you not, with the State Board of Health at one time?

A. Yes, sir. That comes in the second period that I referred to, when I was largely employed on sanitary questions at Chicago. I was employed by various agencies, the City of Chicago, by local committees interested in the matter, and also by the State Board of Health, in connection with the examinations at Chicago and the streams of Illinois, the Illinois River and its tributaries.

Q. As to the sanitary conditions of those streams?

A. Yes, sir. The State Board of Health undertook to co-

operate in the investigations that we were making at Chicago between 1885 and the passage of the Sanitary District Act in 1889, and made a very comprehensive series of analyses of samples through one summer and one winter, taken at various points between Lake Michigan and the City of St. Louis, in order to determine the question of the self-purification of sewage introduced by the Illinois & Michigan Canal from the City of Chicago.

Q. You have made studies of the hydraulics of the Great Lakes, have you not, Mr. Cooley?

A. Yes, sir.

Q. Of water levels and changes in oscillations and so forth of the lakes?

A. Yes, sir, I did that as early as 1881, when I was connected with the Government service at St. Louis, when the matter of the reservoirs at the headwaters of the upper Mississippi was under consideration, in the aid of low water navigation.

I then made a study of the possibility of utilizing this great natural reservoir in passing waters by way of the Des Plaines and Illinois Rivers to the Mississippi River; and gave the matter general consideration at that time.

Later, I took up the matter as part of my duty as chief assistant to the Drainage and Water Supply Commission in 1886 and 1887. I followed the matter up, prepared a paper upon the subject matter in 1888, and brought the whole subject matter into final form in a series of papers before the Western Society of Engineers in 1888; printed early in 1889.

I later gave it further consideration, while a member of the International Waterways Commission. The instructions of Congress to that Commission were that we consider in full the water supply in connection with the development of ocean navigation into the lakes from the Atlantic Seaboard. At that time I brought together all the material that had formerly been gathered; and obtained from the United States and Canada and the cities about the Great Lakes all the records that had been made going back to the beginning of the last century, in regard to the fluctuations of the lakes, the elevations of the lakes.

Q. And their oscillations from time to time and hour to hour?

A. Yes, sir. And the Commission at that time did recommend that there should be undertaken a comprehensive series of measurements through a wide range of fluctuations, for the purpose of definitely ascertaining what the relation of out-

flow was to stage of water. And they did further give the opinion that for such navigation as they recommended, 30 feet of water, would require that the levels of all the lakes should be controlled.

The Canadian Government has recently undertaken to carry out the substantial recommendations of the Commission, and has started to construct the St. Lawrence waterways on the basis of 30 feet, and have let contracts on the Welland Canal for that purpose.

Q. Did you have occasion in this time to make a study and examination of the necessities of the navigation interests and the improvement of navigation at Chicago and through the Illinois and Des Plaines Rivers?

A. Yes, sir. That proposition was in view from the inception of the drainage enterprise, and in fact you might say from the time that the Chicago divide was discovered, in 1673; and it was a part of the policy of this State from the beginning to procure the construction of a waterway through the State. And when the Chicago sanitary question came up, and it was determined that the solution would require a large canal across the Chicago divide, the State, through its General Assembly, took the view that it should be constructed so as to lend itself to the development of a deep waterway through the State. And so from the beginning, the effect of this water which was needed for the sanitation of Chicago upon the regimen of the Illinois River and of the Mississippi River; and how it could be utilized in producing a waterway, was a prominent factor and an important factor also in determining the policy of the State in granting the privilege to the City of Chicago of sewage disposal in the manner proposed.

Mr. Hopkins: I move to strike out that entire answer as not responsive to the question, and as incompetent as to what anybody intended with reference to the policy of the State, or what the legislature had in mind; and as incompetent and immaterial.

Mr. Adcock: Q. You are familiar with the action of the State in connection with the matters which you have mentioned, and you attended, did you not, at different times the meetings of the Senate and House of the General Assembly of this State?

A. Yes, sir; I am familiar with the history of the State prior to the time when this matter was taken up. I acted as consulting engineer to a special joint committee of the General Assembly, which framed the Sanitary District law

and was familiar with all the considerations that influenced that law, in Chicago and in the valley.

I was at Springfield during the entire consideration of the matter, and had general charge in the latter part of the session of the bill for the City of Chicago, for the City Council of Chicago and for the several civic organizations of Chicago, and I believe that I know as much about what the policy of the State was at that time, as anybody can know.

I drew some supplemental measures known as the Little Waterway Bill and the joint resolutions of 1889 and also of 1897, which were passed by the General Assembly, declaring the policy of the State.

Mr. Hopkins: I renew my motion and add to it the further ground that it is not the best evidence.

Mr. Adcock: Q. You were familiar also, were you not, Mr. Cooley, with various reports of the Government engineers that were made prior to 1889, referring to the report of 1867?

A. Yes, sir; I had at that time been over all the documentary evidence in relation to the subject matter, reports of various kinds, going back to that of Long in 1816, Major Long; Phillips and Graham, in 1819, and to the report of General Gratiot, in 1834, in which the United States proposed at that time to construct a channel 10 feet deep and 100 feet wide; the land grant to the State of Illinois to aid in the construction of the Illinois and Michigan Canal; the report of the survey and examinations of John B. Preston, in 1857 and '58.

Q. Who was Mr. Preston?

A. John B. Preston, was a civil engineer in the State of Illinois, who made a project for steamboat navigation between Lake Michigan and the Mississippi River, in which the low water navigation of the Illinois River was to be made by aid of a water supply from Lake Michigan.

That proposition was followed up by joint resolution of the General Assembly in 1861, which called upon the canal trustees to examine the subject mater.

In 1862, there was a bill in Congress providing for such a waterway. The Honorable Thad Stevens made a speech, in which he denounced the proposition as a measure to drain Lake Michigan and convert it into a cornfield. So the objection on this lake diversion proposition goes back a long ways.

In 1866, General Wilson was charged with the duty of making a survey, and based his report of 1866 and '67 on the notes and data collected by John B. Preston in 1857-'58.

In 1867, General Wilson by the aid of a special appropria-

tion from Congress made a survey of his own, which was reported upon in December of that year, and there was also a report on the Upper Illinois River by Colonel McComb, 1874 and by Major Benyaurd in 1883; and also upon the enlargement of the Illinois & Michigan Canal in connection with the Hennepin Canal in 1882-4, and by the Comstock Board in 1886 and '87.

All these documents gave a very complete idea of the physical conditions of the Illinois River and its possibilities of development, and were available prior to the passage of the Sanitary District Act.

I omitted to mention in the list, as long as I have gone into it, the fact that Howard Stansbury, United States Engineer, made an examination of the Illinois River in 1838; and that General Joe Johnson, later of Confederate fame, was upon the river engaged in improving the same in 1852 and '54. We had all that material.

Mr. Hopkins: I move that that answer be stricken out for all the reasons assigned in the last objection.

Mr. Austrian: I want to state in this record now that the motion now is in direct violation of stipulations between the District Attorney and ourselves. The District Attorney has agreed with us repeatedly, both in and out of this record, that it was not necessary to produce original documents, as long as we gave the source of the information from which the witness testified; and if upon examination it was found to be correct, no such question would be made or pressed.

Mr. Hopkins: I am not familiar with the stipulations made. If that is so, any stipulation will be lived up to.

Mr. Austrian: It has been made outside the record by the District Attorney and ourselves repeatedly and the Government's evidence has been produced upon that theory. Witnesses have been permitted to testify repeatedly without the introduction of documents, so long as they gave the source from which they testified.

Mr. Adcock: Q. You were the chief engineer of the Sanitary District for a time, were you not?

A. Yes, sir; I was the first chief engineer from January 1890 to December of that year; and a year later, December, 1891, I became a trustee of the Sanitary District and the chairman of its engineering committee until the close of my term in 1895.

Q. Will you describe the physical conditions here at Chicago and the surrounding territory, with reference to the topography of the country?

A. The Chicago River basin, as it originally existed in nature, consisted of the North Branch and its drainage basin, together with the South Branch, an area of about 240 square miles (now about 300 square miles). West of the Chicago River basin, was the Des Plaines River basin, drained by the Des Plaines River which ran parallel to the lake from the headwaters in Wisconsin down to a point about ten miles from Lake Michigan at Lyons; and then leading southwesterly to a junction with the Illinois River, or to the junction with the Kankakee River, which formed the Illinois.

This Des Plaines River, in the vicinity of Lyons, had a low water elevation of about eight feet, and a drainage area of 633 square miles.

The divide between the Des Plaines River and the Chicago River was in the vicinity of the Bridewell, just west of Kedzie avenue, and had an original elevation of about 10½ feet above Lake Michigan, and whenever the Des Plaines River rose from two or three feet above low water, or exceeded a volume of about 1,000 second feet, the flow of the river divided, part of it coming through the South Branch of the Chicago River to Lake Michigan, and in great floods 60 to 70 per cent. of the entire flow of the Des Plaines River came to Chicago.

This condition existed up to about 1854, after the Illinois and Michigan Canal had been opened in 1848, when the Drainage Commissioners cut out the original divide at Kedzie avenue and drained out the Mud Lake region as it was known in Voyageur's days, and on the original land maps as "Portage Lake, Portage Swamp, and Portage Slough."

For a number of years thereafter, the entire flow of the Des Plaines River came in the direction of Chicago except at such times as in the fall and winter when the ice interests of the Des Plaines River Valley made a temporary dam in order to fill the ponds on the 12-mile level between Summit and Lemont, for ice-making purposes.

Finally the flow from this source became such a nuisance to the City of Chicago that after 1870 they constructed the Ogden-Wentworth Dam. That crossed the old Portage Slough at the range line at Summit, at an elevation of something over 11 feet above Chicago datum. And this was overflowed also, whenever the river rose above a volume of about 1,000 feet per second; and the waters continued to come this way in flood times when the volume exceeded that amount until 1893, when the Sanitary District executed its river diversion and created a spill-way above Summit, which restricted

the flow down the river until the volume reached between 3,000 and 4,000 feet per second. And in about 1909, this was finally closed, so that no waters from that source have come through the Chicago River to Lake Michigan since.

The effects of this overflow have been most pronounced and is noted from time to time in the narratives relating to Chicago and its portage. For a portion of each year boats in the fur trade made the trip from the Chicago River to the Des Plaines River and down the Illinois to the Mississippi River without any portage at all. For a portion of each year, a portage of two miles was required; for another portion seven miles, and in very dry seasons the portage was 51 miles to the junction of the Des Plaines and Kankakee Rivers at Dresden. Those conditions were availed of in trade and travel, from the time of the Discovery down to the time of the removal of the Indians from the State of Illinois in 1836.

The first white settler of Chicago, or the first white man to domicile here was Marquette, in 1674-5, and he was driven from his cabin on the West Fork of the South Branch near Robey street by a flood that came over the divide; and the next day he resumed his journey down the Des Plaines and Illinois Rivers without making a portage.

In 1832, the United States made an appropriation for opening the mouth of the Chicago River, and projected two piers from the vicinity of the present site of Rush street bridge, across the sand spit into the lake; and made a single dredge cut across the bar. This bar was washed out in 1834 by one of these floods that came across the divide.

A schooner entered the port of Chicago for the first time after this flood.

In 1849, a great flood came over the Divide and cleaned out all the bridges in the Chicago River, wrecked all the shipping, producing a great disaster for its day.

The same thing was repeated in 1858.

In 1881, the water came over the Divide for probably six weeks or eight weeks continuously, in large volumes.

In 1887, I measured a flow coming across the Chicago Divide of 7,000 feet per second, the flood of that year.

In 1892, this flood condition was very critically examined from the Chicago River to Lake Joliet, and a steamboat drawing three feet of water could at that time have gone from the Chicago River down to the Illinois River, and returned, in the absence of bridges. Aside from these conditions re-

specting the flood waters, the site of Chicago itself was substantially a morass, similar to what exists adjacent to the Calumet River up to a recent time, and still exists in some sections, awash in high waters of Lake Michigan, and overflowed in all these flood times. It was of much less extent than the Calumet marsh region; and along the lake shore there were the remnants of a sand spit, and wind blown sands rising from 10 to 20 feet above the lake; but generally behind that and out to the slopes beyond, the low lands bordering the Chicago River, the banks were only three to five feet high at low water, and consisted of ooze and muck and alluvial clay, interstratified with layers of sand.

Mr. Hopkins: I make the same motion for the same reasons, but on the statement of counsel as to the stipulation I withdraw any objection on the ground that it is not the best evidence, insofar as the witness has testified as to matters contained in public documents, which I understand to be contained in the stipulation.

I also make the further motion to strike out such parts of this last answer as have already been covered in certain written documents that have been offered by the defense and agreed to by the Government, subject to the objections of materiality and competency, as simply repetition.

Mr. Adcock: Q. You are familiar with the establishment of the water supply and sewerage system of the City of Chicago, are you not, Mr. Cooley?

A. Yes, sir, I looked up all those matters and wrote a digest upon the subject, in connection with the investigations that I was connected with at Chicago.

Q. Will you state the various steps that have been taken by the City of Chicago, and towns and villages adjoining it, in the years past, to establish its water supply and sewerage system?

A. The City of Chicago, or Village of Chicago was organized on August 10, 1833, 28 electors voting; population estimated at 350, from which I presume that none except those that were running for office voted.

At that time it was a mere frontier camp, and the usual well 6 to 12 feet deep in the front yard; slops thrown in the back yard; a privy vault on the back end of the lot. The soil conditions very soon made this intolerable, and the floods occurring annually diffused the deposits on these lots, without regard to sanitary discrimination.

As early as 1836, the conditions had so developed that

the people were taking their water in pails from the river and from the Lake Shore; and the first water system of the City of Chicago consisted of barrels mounted on two wheel carts, that were backed down into the lake and peddled on routes, much like the milk routes to-day.

As early as 1836, a franchise was granted for a water company to supply the citizens with water, but owing to the panic of 1837 and the financial stress of that period, this company did not get its works installed until 1840; and these works consisted of a 250 barrel tank mounted on blocks at the foot of Lake street, with a 25 horse power engine, a short pipe intake into Lake Michigan and two miles of log pipe, bored out by hand; laid in the streets as a distribution system.

The people of even that day were adverse to monopolies, and did not patronize this water company to the extent of making it a financial success; still preferring the institution of a barrel on two wheels. So in 1851, a charter was granted to a water company, a new water company. The city had been organized in 1837 with a population of about 4,400 to 5,000 in 1840. In 1851, the population had reached about 35,000 and a new water company had been chartered; but the city finally took over the whole proposition in 1854 and established the works at the present site at Chicago avenue on the North Side.

There was some discussion at that time in regard to whether the site should be on the north side of the river or the south side of the river, but the general opinion prevailed that there was a lake current tending southerly along this shore, and it would be safer from pollution to put it on the North Side.

There was another event happening about this time, the opening of the Illinois and Michigan Canal in 1848. The first shovel had been thrown on this Canal at Bridgeport within the present city limits July 4, 1836; and that had contributed greatly to the growth of Chicago during its construction.

The first railroad out of Chicago was opened out to Elgin, also in 1848. The Michigan Southern Road came to Chicago in 1852.

There was a sickly period in Chicago between 1849 and 1854, in which the death rate rose to 48 to 50 in a thousand; three times what is now normal to well sanitated cities.

All these events, what was happening to the water supply, the death rate which had grown so enormously, the feeling that Chicago had ceased to become a mere camp and had a

future before it, led the citizens to make an extraordinary effort to better the conditions here, in order that she might realize destiny. And so in 1855, or 1854, Mr. E. S. Chesbrough, of Boston, was employed as the Sanitary Engineer of the city; particularly at that time to devise a sewer system. Mr. Chesbrough went abroad and studied the conditions at Hamburg and at London and other foreign cities in 1856-7, but had submitted plans for his sewer system late in 1855.

In that connection I desire to say that this was the first comprehensive sewer sytem in the United States, and that we had at that time about 75,000 to 80,000 of population; and that other cities in the United States like New Orleans have only had a sewer system within the last ten years. Baltimore has not yet completed a sewer system.

I will say further that it was the second comprehensive sewer system built in the world. Hamburg had built a sewer system after its great fire, about 12 or 14 years before. London had started a sewer system, but its plans were not yet complete, and were not completed for three or four years later for a comprehensive system.

The state of the art up to that time had been that all human wastes were excluded from sewers by law. That was the law in England. And it was not until the report of the cities and towns commission in 1844 in England that that law was changed. At that time there had received general acceptance the filth theory of disease, and England and the Continent went on a general clean-up, you might say.

Berlin did not have a sewer system until 1860. All human wastes were excluded from the sewers of Paris up to 1880, so Chicago was a generation or so ahead of the world, and led the United States in regard to its sanitary provision in 1855.

Mr. Chesbrough planned his sewers so as to give a seven foot basement under the buildings, and as a result the grades of Chicago were established at 10 to 12 feet above city datum.

Q. That is the street grade?

A. Street grades; and in many places the sewers were built on mounds entirely above the level of the ground, the natural ground, or on embankments; and walls were built on the curb line; and that is the reason for the general condition that you notice in Chicago, that the basements all go out to the curb line so as to save the filling required to cover the sewers; and the sidewalk space beneath, which does not exist to the same extent in any other city.

After the Great Fire, the grade was again re-established

to the present level of 14 feet above the city datum. I was here in 1872, after the Great Fire in 1871, and remember distinctly the condition, that the sidewalk of the city was going up and down at every street crossing, on account of the new grades.

The sewer system then planned by Mr. Chesbrough discharged for the most part to the river. No sewers entered the lake on the north side, on account of the water supply. And the early main sewers came to the main river, so as to be within the influence of any circulation that might be established by way of the Illinois and Michigan Canal. The only sewers that were planned toward the lake was the one east of State street on 12th street and at 22nd street; and later when the city was extended down to 39th street, the 35th street sewer was added, also discharging into the lake. These plans were followed out substantially with the raising of the general grade of the city; and the conditions on the unimproved low lands continued as observed by me in 1872 and 1874 to 1878. Meantime the condition in the river itself was becoming intolerable.

I wish to say in that connection that on account of the great cost of raising the city to the grades required to produce a sewer system, the trunk sewers were laid on extremely low grades, 2½ to 4 feet per mile, which constituted them sewers of deposit in low water, under conditions of dry weather flow. And it was recognized from the beginning that catch basins and sewers would have to be cleansed from time to time, and it was only in storm time when the sewers were running substantially full that the sewers were self scouring, that is the trunk sewers.

The conditions in the river early became intolerable with the growing population. We had reached 125,000 by 1860. Chicago early became a packing center, and winter slaughtering was practiced at that time, before they had the refrigerator methods which permitted of all the year around slaughtering. And there had not been introduced at that time the saving in the by-products, bloods and other matter (this has since become a feature of Chicago slaughtering institutions), and everything went to the river, and so the river, particularly in winter time, became very bad.

Under some arrangement, which is indefinite, the pumps were operated during the later fifties in the interest of a better river.

Q. That is the pumps on the Illinois and Michigan Canal at Bridgeport?

A. Yes, sir, I will speak of that. The Illinois and Michigan Canal, as it was finally completed under the canal trustees, had a summit level 8 feet above Lake Michigan, and it was fed in ordinary seasons from the Des Plaines River and by a feeder through the Sag Valley and the Calumet River at Blue Island.

Q. That was known as the Shallow Cut Plan?

A. Yes, sir, where a dam was built across the Calumet River at an elevation of 11 feet above Chicago datum. This was insufficient in the dry seasons, and a Dutch Wheel or Lift Wheel was erected at Bridgeport, at the forks of the Chicago River and at the head of the canal for the purpose of supplementing the feed water of the canal, and in such seasons that was sufficient in cleansing the Chicago River and as I have stated, these were operated for that purpose in the later fifties.

But in 1863, after Chicago had established a Board of Public Works, the Chicago River became very offensive. An erysipelas epidemic occurred, which was co-terminus with the South Branch and was attributed to the blood and other matters from the slaughtering houses, and it was depicted on the spot maps as the "Valley of Death."

The Board of Public Works at that time made an arrangement with the Canal Trustees by which the Bridgeport Pumping Station should be operated and the city would contribute to the cost of doing so for the purpose of cleansing the Chicago River; and that arrangement continued up to the time that the canal deepening was completed in July, 1871.

Q. That was completed then on the Deep Cut Plan?

A. Yes, sir. I will speak of that later. That was in July, 1871. Meantime the effluent from the river was contaminating the water supply, and Mr. Chesbrough projected the first lake tunnel in 1862. It was authorized in 1863. It was to be five feet in diameter, and extended out to the crib two miles from shore, and it was thought that this would give immunity for a long time in the future. It was believed that the effluent from the river for the most part would stay near the shore line, and would not reach out that distance into the lake.

Nevertheless, in designing that tunnel, he made his plans in such a manner as to invite an extension in the future without disturbing the existing conditions, providing an exten-

sion out from the crib in a separate shaft, so it could be shut off and extended at a future time.

This work was severely criticised by all the wise men of Chicago at that time, and Mr. Chesbrough's life was made a burden to him, but in 1867 it was opened, and attracted the attention of the world and made the reputation of Mr. Chesbrough as an international engineer. It has since been followed in all lake cities and followed in all water works practice, to the extent that tunnels can be made available.

He immediately followed this tunnel with a seven foot tunnel parallel to the five foot tunnel, leading from the same crib by way of the Chicago Avenue Station southwesterly across the city some four miles from Chicago avenue to 22nd street and Ashland avenue. That station was opened in 1874.

The Chicago River at this time was in a deplorable condition. I was in Chicago nearly every day, or several times a week, from 1874 to 1878, and made a study of the conditions here, and was personally very well acquainted with Mr. Chesbrough. The North Branch, as I used to ride by it, between Evanston and the city, in the heated term of summer, exhaled an effluvia that compelled the passengers on the Northwestern Road to shut down the windows in order to keep themselves from being nauseated. No words can describe the potency of that smell.

This condition led Mr. Chesbrough to project the Fullerton Avenue Conduit, started in 1874 for the purpose of circulating the waters of the North Branch. I examined and wrote an article on that conduit while it was under construction. It was put in operation in 1878, and as operated it changed the waters of the North Branch about once in three days, which greatly mitigated the badness of the smell. But it was still far from a satisfactory exhibit.

The South Fork conditions were even more serious than the North Branch; the smell from that source reaching out to the lake shore in the then best part of the city, down in the vicinity of the Douglas monument and above. This was noticed particularly in the night time and on foggy days. The sun seems to have some resolving powers in dissipating these smells.

Mr. Chesbrough projected a similar conduit to the South Fork, but his enterprise in behalf of the welfare of the city by that time had reached such a magnitude that he was unable to carry out that enterprise, and we retained the con-

ditions of the South Fork with us until the Sanitary District finally changed the same along about 1908, I think.

Meantime, a Commission had proposed the deepening of the Illinois and Michigan Canal on the original plan; and in 1865 an enabling act was procured from the General Assembly which authorized the City of Chicago to deepen this canal on the original plan for sanitary purposes; and the city of Chicago did so, and expended thereon about Three Millions in cash and opened the same in July, 1871.

Q. That was a gravity flow, wasn't it?

A. Yes, sir, gravity flow.

The General Assembly was called in special session after the Great Fire of October, 1871, and repaid this money to the city of Chicago, and it was all the funds that it had until the city was in shape to again realize taxation.

This canal as originally projected and worked on from 1836 to 1841, when the state went broke, had a declivity of a tenth of a foot per mile or 2.9 feet between Bridgeport and Lockport. But when work was resumed under the trustees for the bond holders in 1843, they adopted the expedient of a temporary level 8 feet above Chicago datum for 26½ miles, which I have already described.

Q. What was the height of this divide above Chicago datum?

A. The original divide at Kedzie avenue was about 10½ feet above Chicago datum.

Q. That was called the "Continental Divide"?

A. Yes, sir, Continental Divide, but this was a mere alluvial deposit. The real divide was the rock floor at Lemont, which was between 7 and 8 feet above Chicago datum, and about 2 or 3 feet above the high water of 1838, which was the highest water on record. The original divide was only 5 to 6 feet above high water of 1838.

Shall I proceed with the statement?

Q. Yes, proceed with the answer to the original question.

A. This was the only relief that the city had until the canal was reinforced by pumping works in 1883. The canal when opened to gravity is estimated to have carried out 40,000 cubic feet of water per minute. But the lake was then high, and in later years as the lake fell, the capacity shrunk to 15 or 20,000 feet per minute, which was scarcely more than the dry weather flow and the water supply of the city, so it was ineffective in preventing the sewage from flowing towards the lake. And the condition of the canal became so

bad that at the instance of the State Board of Health, first in 1878, when it was organized, I think, in 1877, the Munn Resolution was passed by the Legislature in 1881, calling upon the city of Chicago to erect pumping works there of a capacity of not less than 60,000 feet per minute. These pumping works were installed in 1883, but were not actually accepted from the contractors and taken over by the city until 1886, although they were operated meantime.

I made a test for the city in 1886 in regard to the capacity of these pumps and works, and as to the contract having been carried out; and also at that time I made a comprehensive series of measurements in the Illinois and Michigan Canal, to establish its capacity in relation to the stage of water. And I think that determination was used ever afterwards, as long as the canal was operated by the pumping machinery.

These pumping works were instituted or authorized, or directed by the Legislature in response to the representations of the State Board of Health, which had taken a position supported by the report of Superintendent Thomas that the canal could be made to carry 100,000 cubic feet of water per minute, and that such a volume of water would dilute the sewage substantially beyond offense. But they did not get the recommendations carried out except with the minimum limit of 60,000 cubic feet. It was for the purpose of relieving the nuisance at Joliet, and in the Valley further down; and also for the purpose of purifying the Chicago River that these pumps were installed, or called for by the Legislature.

I left the city in 1878, and was engaged upon Western River Improvements until late in 1884. And the only thing that I did that had any bearing upon the Chicago problem was to examine the question of the feasibility of taking a water supply out of the lakes by way of the Des Plaines and Illinois River, for the low water improvement of the Mississippi River, about 1881.

There was one conversation with Mr. Chesbrough, which I would like to refer to because it has a bearing upon matters which came up later. Mr. Chesbrough was uncertain in his own mind in 1878 as to what the future solution of the sanitary question was to be. He had planned along the line of the State Policy, which had contemplated from the beginning the flow of water in the direction of the Illinois Valley, and which comes up from time to time in all the actions of the state. But the city was unable to finance a proposition of

that kind. Conventions had been had, reports had been made; there was a Great Waterway Convention in 1847 and again one in 1863, in which 14 states were represented, urging this project; the Board of Public Works had considered it in 1860, so the matter was a familiar one to the people of Chicago, the idea that eventually sewage disposal was to be down the Des Plaines and Illinois Valley.

I asked Mr. Chesbrough, late in 1878, before leaving the city, whether that was not going to be the final outcome, and he made this reply: That that solution would be ideal when this city reached a million inhabitants and was able to finance the undertaking, but he was unable at this time, with his knowledge of the growth of American cities, to project works on the theory that Chicago would reach a million inhabitants in such reasonable time in the future as would justify the investment.

The only incident that occurred of particular moment between 1878 and 1885, was the Great Flood in the Des Plaines River, which I investigated, secured all the data that was possible. This flood reached a magnitude of 13,000 second feet; continued at a uniform elevation for about four days; gradually shrunk, but exceeded 10,000 feet per second for 21 days, at Riverside. There was probably from five to 8,000 cubic feet per second coming across the Chicago Divide during that time; and a lesser amount probably for two or three times as long a period. In addition there was probably a maximum flood from the Chicago basin of not less than seven to 8,000 feet. These conditions swept the Chicago River clean and led the people of Chicago to renewed earnestness in the consideration of their sanitary problems. Between that time and 1885 various projects were mooted, one of which was to shift the water supply to Grosse Point, the North limits of the city of Evanston; another to shift it to Highland Park in Lake County, and let the water come down by gravity. Another was a deep cut proposition which was worked up by Mr. Matthiesen at Joliet, by which a narrow and deep channel with high velocity was to be constructed from the Chicago River and located between the Illinois and Michigan Canal to the Des Plaines River; and discharging in the upper basin at Joliet.

The Citizens' Association of Chicago had taken particular charge of this matter and had worked up this latter proposition of Mr. Matthiesen's and made a report thereon. On August 2, 1885, occurred a rainfall of over 6 inches in 24

hours, the greatest precipitation that has occurred during Chicago rainfall record, beginning in 1843. The effect of this rainfall was to sweep out the contents of the Chicago River; to scour out all the sewers and catch basins and to wash the streets. The entire effluent went into the lake and filled the lake with a black filthy mass extending several miles north and south along the shore, and out beyond the crib. And its effect was visible in the water supply for a long time afterwards.

The Standing Committee of the Citizens' Association appointed a sub-committee consisting of Mr. Ossian Guthrie, who had operated the Bridgeport Pumping Station, since its installation in 1848 up to the time it was abandoned in 1871 by the deepening of the canal. He had ice interests in the Des Plaines River, and was thoroughly familiar with all the flood conditions at Chicago. They selected also Doctor Frank Reiley, who was then the Assistant Secretary of the State Board of Health of Illinois, and they selected me as engineer.

We made a general examination of the situation, visited the Des Plaines River and all the points of interest in connection with the phenomena, and wrote a report which I drew; and this report substantially unchanged was adopted by the General Committee of the Citizens' Association, and printed in all the Chicago papers on August 27, 1885. A rainfall not quite so large occurring a week or two later, also producing a large flood, came in to re-enforce the findings of the report and give them general credence and acceptance among the people.

This report contemplated or recommended that all storm waters including all sewage be permanently excluded from Lake Michigan; that a channel large enough to accomplish this be built through the Des Plaines Valley to an outlet near Joliet; and that in order that this channel should not be unnecessarily large, the headwaters of the Des Plaines and North Branch should be diverted to Lake Michigan. Of course it involved taking out all the sewers and reversing them, or intercepting those that emptied into the lake; and also providing a circulation in those parts of the river which had no circulation; parts of the harbor.

This proposition was followed by an ordinance of the Council which I drew, and which was promptly vetoed by Carter Harrison, Senior, on the ground that the city had no means of financing the undertaking; and it was vicious to discuss these propositions, and unpatriotic under those circumstances.

Later Mr. Harvey B. Hurd, went to Mr. Harrison and pointed out to him a constitutional method of raising money through the creation of a blanket corporation, such as we have precedent for in the Park Boards, with its own power of taxation and bonding. Mr. Harrison later sent a message to the Council recommending the appointment of an expert Commission, and this was adopted.

In April, 1886, Mr. Rudolph Hering of Philadelphia was selected as Chairman of the Commission, and later Mr. Samuel B. Artingstall, who had been Assistant Engineer to Mr. Chesbrough and was then City Engineer, was made a member; and also Mr. Benezette Williams, who had been an Assistant Engineer to Mr. Chesbrough, and who had recently completed the Disposal Works at Pullman, which were looked upon as model works at that time, and an augury of the future disposal of sewage, by scientific and rational methods. I became chief assistant in general charge, in the absence of Mr. Hering, of all the work, and in special charge of those parts of the investigation which we are particuary concerned with in this inquiry.

I had the subject of streams examination through all the water sheds that affected the Chicago condition, the lake currents, lake levels, the ship canal surveys, borings, calculations of the capacity of channel; the Illinois River problems; its effect on the Illinois River of the proposed flow of water from Lake Michigan; the examination of the Chicago River and its contents and of the special filth producing industries; an examination of the conditions of the Illinois and Michigan Canal; an examination of the conditions produced in the Illinois River by the sewage which had been sent down the canal. Mr. Swan of Boston had particular charge of the investigations relating to land disposal, sewage treatment and lake disposal. Mr. Swan was a man who had been connected with the Massachusetts Board of Health, which had made perhaps the most extensive researches up to that time respecting the pollution of streams; and he had also made a number of trips abroad.

Recess to 2:30 P. M.

After Recess, 2:30 P. M.

LYMAN E. COOLEY resumed the stand and testified further on direct examination as follows:

The Witness: I wish to supply an omission respecting the consideration of the report of the Sub-Committee to the Drainage Committee of the Citizens' Association. I had included in that report a statistical statement to show that Chicago would reach one million inhabitants in the year 1890, and would be able to finance the undertaking. I was asked to strike out that matter as it would discredit the report, as nobody in Chicago believed that this city would reach a million inhabitants in the year 1890. There was no member of the Committee who believed it; and so I struck it out, as it had no material bearing upon the project itself. There were on that Committee such citizens still living as J. J. Glessner and J. Harley Bradley.

In my own work relating to the phenomena of lake fluctuations and lake currents, I carried out the most extensive series of observations ever made upon that subject.

In 1875 and '76, I made an investigation for Mr. Chesbrough on the record of an automatic gage kept on the Chicago Crib, and for the first time worked out the phenomena of seiches, there exhibited. These oscillations are characteristic of Lake Michigan, and have periods of 20 minutes; are never quite absent; sometimes reach amplitudes amounting to feet. I demonstrated by means of the formula respecting waves of translation in deep water, in connection with the Lake Survey charts, that period corresponded to a travel to the opposite shore and back. Later I found that these phenomena had been examined on Lake Geneva in Switzerland and on the lochs of Scotland; and that a pendulum formula had been adopted to express the conditions.

I also discovered, but this was not so well demonstrated, a longitudinal oscillation in the lake from end to end, which had a time interval of something over an hour. I kept an automatic gage at the foot of Randolph Street for four years, and had occasion to repeat the studies in this matter between the years 1886 and 1900.

I also ascertained, but this had been investigated by Colonel Graham, that there was a tide in the lake amounting to 2½ inches at springtide, occurring daily and not twice a day, as on the Seaboard.

Mr. Hopkins: For my own information, I would like to know what the original question was. Wasn't it simply something about the sewer conditions in Chicago.

(Question read as follows): "Will you state the various steps that have been taken by the City of Chicago, and towns and villages adjoining it, in the years past, to establish its water supply and sewerage system?"

The Witness: I will say that this investigation in 1886 to 1887, was taken as part of the investigation respecting the water supply of Chicago, and was conducted by me under the instruction of the Drainage and Water Supply Commission.

Mr. Adcock: Q. That was a Commission in which the Commissioners were appointed by the Mayor, were they not?

A. Yes, sir. I have already given the history of that.

Mr. Adcock: Yes.

The Witness: The only thing further that I will add at this time, in connection with the lake phenomena, is in relation to the currents which we found to be due solely to the winds; and that they traveled northwardly along this shore for $\frac{2}{3}$ to $\frac{3}{4}$ of the summertime and southwardly for $\frac{2}{3}$ to $\frac{3}{4}$ of the wintertime.

I also made a critical examination of the Chicago River and its contents, and dredged up every acre of its bottom within the city to ascertain the nature of the deposits there occasioned by sewage. The Chicago Harbor has an area of about 450 acres, which was actually used for shipping purposes. This river, as I have already stated, was swept clean in August, 1885.

In the fall of 1886, it had a sludge deposit in the North Branch from a foot and a half to 6 feet in depth; and in the South Branch about 4 feet in depth. This sludge was not what is ordinarily termed sludge in the nomenclature of sewage disposal. It was a black, jelly-like mass full of cavities like Swiss cheese, indicating a secondary decomposition, and emitting gases on its own account; and from all the studies and examinations and knowledge which I could acquire in regard to the same, it appeared to be largely hydro carbon, bacterial gases that are thrown down through the decomposition. I estimated that the South Fork would have filled up in four years from these deposits, except for the progressive decomposition that was going on.

I repeated this examination after the spring flood of 1887, and found that the river had been swept clean of these deposits.

Q. Those went out into the lake?

A. Yes, sir, they were of that constitution, so cellular in composition that when they are once broken up by a propellor or other disturbing forces, they would float readily in the water.

I also made an examination of the Illinois and Michigan Canal to ascertain its condition respecting these sludge deposits and what current must be maintained to keep the same from settling upon the bottom. I found practically no deposits similar to those which I have described in the Illinois and Michigan Canal. There were deposits in wide waters, which consisted very largely of earthy matters; and it seemed to be that a velocity of $\frac{1}{2}$ to $\frac{3}{4}$ of a mile would maintain all these substances in suspension.

I also made an examination of the conditions in the Illinois Valley since the sewage had been down there through the canal, and made an extended trip from Joliet to La Salle, interviewing all the people and fishermen who were familiar with the conditions in the river, respecting that subject.

We had a breakup flood in 1887, occurring the latter part of February, which reached 10,000 second feet at Riverside, but was of extremely short duration, as a freezeup set in the next day, after the flood got fairly under way. I measured that flood in the North Branch and in the West Fork of the Chicago River, where I ascertained that 7,000 second feet was coming across the Divide. I also had a party at Riverside. Mr. Hering was in personal charge of a party at the mouth of the Chicago River, and as I recall measured 12,000 feet of water going out into the lake in that flood, which was by no means an extraordinary flood.

A preliminary report of the Commission was made January 30, 1887, and in that report they considered three methods of sewage disposal for Chicago.

One of these methods was to gather up the sewage by intercepting sewers and conduits, and pump the same to the sand ridges and dunes of Indiana, east of Hammond, and between the Little Calumet River and Lake Michigan; and there dispose of the sewage on land by broad irrigation and intermittent filtration. This scheme was regarded as impracticable by reason of divers political jurisdiction, and by reason of cost. And it still left problems to be solved in the circulation of rivers and the care of floods. It was known even at that time, and more fully developed later, that the conditions of flood waters and especially the conditions of the wa-

ter in the Chicago River when this city was taking a bath, the sewers were being scoured out and the streets washed, was worse than at any other time. And no such scheme could care for these flood conditions; and the conditions for the maintenance of proper sanitary conditions in the river itself.

The second scheme worked out was like the first, so far as gathering up the sewage was concerned, and a conduit was to be driven out into the lake opposite Jackson Park and the sewage there forced out through this conduit and diffused in the lake. The water supply was to be shifted north to Grosse Point at the Northern city limits of Evanston. This proposition was estimated, and it was also regarded as prohibitive. It was strongly objected to on the score of possible contamination of the water supply even at that distance, as the lake currents showed that to be possible: and also for sentimental and other reasons. The effect would be to pollute the bottom of the lake here over a very large area to be stirred up in storms and result in a bad condition of the water in this end of Lake Michigan. It also failed, like the first scheme, to take care of flood water conditions, and the circulation of the river.

The third proposition, which was affirmatively recommended, was the ship canal solution, substantially as outlined by the report of the Citizens' Association of August, 1885, and the capacity of the channel which it was then determined it would be necessary to take care of the flood conditions was fixed at not less than 10,000 second feet.

This would also take care of the Chicago River and produce proper circulation in its branches by means of adjuncts. The population estimated in all these schemes was two million and a half people, and on that basis the dilution was inferred at 4 cubic feet per second for each thousand of population; although this matter as to what population such dilution would take care of or such volume of water would take care of was not specifically passed on at that time.

It had other collateral merits which were mentioned. It would lend itself to the development of an inner harbor here in Chicago and would provide the water supply required to produce a deep waterway to the Gulf and would contribute to the extent of the cost of the main channel to such deep waterway, without expense to the State or to the United States, all of which were motives which left no doubt as to the proper scheme to select.

Following this report, a bill was introduced in the General

Assembly known as the Hurd Bill, the same being drawn by Harvey B. Hurd, an eminent constitutional lawyer of Chicago, which provided not only for the construction of this work, but also for taking over the sewer system and eventually the water system of the city, so as to combine under one jurisdiction all elements of the sanitary problem in Chicago.

Extensive hearings were had, which were printed at the time, before a Joint Committee of the General Assembly, which went into the merits of the whole question as then understood. The General Assembly considered the subject matter unripe for action and postponed the Hurd Bill, and passed a subordinate bill known as the Roach-Winston Bill, which gave authority to divert the head waters of the Des Plaines River and North Branch to Lake Michigan and enter upon other expedients of temporary relief pending the development of the major project.

The General Assembly also authorized a Joint Committee to sit ad interim to investigate the whole subject matter and report back to the next General Assembly; and constituted the Mayor of Chicago ex officio chairman of this committee.

The Drainage and Water Supply Commission reported on the schemes covered by the Roach-Winston Bill, in July, 1887, and did project various measures of temporary relief such as extending the water tunnels, enlarging the canal out to Summit, or the Ogden Ditch, and putting in pumping works there to pump 120,000 cubic feet of water per minute, but none of these measures were actually carried out.

The investigation of the Drainage and Water Supply Commission continued after this report until November, 1887, and then the Commission was disbanded, without ever having made a final report or completed all the topics which it had undertaken to consider. Following the disbandment of the Commission, I entered into the service of the State Board of Health of Illinois, as its consulting engineer.

The State Board of Health, in co-operation with the City of Chicago, had in 1885 and again in 1886, made an extended series of chemical analyses of samples from a number of points between Chicago and Peoria for the purpose of determining the effect of sewage in the Illinois River and the purification of the same. They presented a very sanguine report in 1886, in regard to the progressive oxidation of the sewage downstream, which was challenged and much criticised by the sanitary world as a misinterpretation of the facts; that the

real cause of the purification shown was sedimentation and dilution, and not purification.

The sanitary world at that time had been much impressed and still entertained the dogma which had been pronounced by the Royal Rivers Pollution Commission of Great Britain, which had issued a dictum much quoted even to this day, that there was not a river in Great Britain long enough to purify itself.

My work with the State Board of Health consisted of various examinations and consultations here at Chicago, special examinations of the Illinois River, in which I twice examined the conditions produced by the distilleries and the cattle pens of the Corn Products factories at Peoria and Pekin, which were producing a condition in the Illinois River at that time for 20 to 25 miles below Peoria only less offensive than that which existed in the Chicago River.

In 1888, they undertook a very comprehensive series of stream examination of the Illinois River and its tributaries, and the entire route from Lake Michigan to St. Louis, and continued these observations into the winter months of 1889. And I undertook to work up the physical facts connected with the flow of the river in that connection. These results were published in a preliminary report in 1889, along with my own contribution respecting the Illinois River System, and were before the Legislature in the session of 1889.

In the spring of 1888, the special joint committee of which Mayor Roach of Chicago was Chairman, got busy and employed Mr. John P. Wilson as legal adviser and he called in consultation eight of the most eminent constitutional lawyers that were then in Chicago and the State, to determine the legal basis of a proposed Sanitary District Act. I was employed as consulting engineer to this committee; and in the subsequent months hearings were had in Chicago and in the Illinois Valley in relation to all matters in controversy.

I was called upon particularly to pass upon and determine the capacity of the channel, and adopted the prior determinations that it should have a capacity of not less than 600,000 cubic feet of water per minute, but that in order that Chicago would be better able to finance it, only the rock cuts were required to have this capacity at the outset; the earth cuts permitting progressive development with the growth of population; and it was so entered in the law, or in the bill then prepared.

The other question that I was called upon most particularly

to consider was the subject of proper ratio of dilution. There was a difference of opinion in the Commission itself and in the hearings, ranging from 14,000 cubic feet of water per minute for each 100,000 of population up to 30,000 cubic feet of water per minute, and the subject matter was finally referred to the consulting engineer to make as exhaustive investigation as possible, and that whatever findings he made in the premises would be satisfactory to all parties.

At that time we had not only our own investigations here in Chicago and in the Illinois Valley, which perhaps were more comprehensive than had ever been undertaken upon a similar subject and upon a much larger scale.

And we had also the very excellent reports of the Massachusetts Board of Health, and some from other New England States going back for 15 years or more, dealing particularly with the subject of river pollution. We had also all the reports that had been made by Royal Commissions in Great Britain; the reports in regard to Paris and Berlin, and other foreign data.

In addition to this, I made a special compilation of the population of American cities in relation to the low water supplies of streams into which they discharged their sewage. So I felt then, and feel now, that we had all the data which was available for such a consideration. We had on the one hand a city so situated and conditioned that all the sewage that was produced by its population was practically tributary to the sewer system, perhaps more completely so than in any other city of the world. We had also at that time the established leadership in the preparation of food products of vegetable and animal origin, and the waste from those sources in themselves amounted to the equivalent of a very large city. But in respect to this matter, it was reasoned that there had been a very great development in by-products from these industries in the past, and that probably by the time the capacity of the channel approached exhaustion these wastes would be all converted into useful commercial products, so that there would remain substantially only the domestic sewage in the eventual windup.

On the other hand most of the data existing here and abroad were cases of actual pollution of streams, of natural streams which were all highly charged, in some cases to their practical limit in digesting the organic remains from the land. That matter had come up for very careful and full consideration in the studies by the State Board of Health, or under

the direction of the State Board of Health, and we had made estimates of the organic product from the Illinois watershed, a very rich watershed, in its vegetal cover, which showed that the organic wastes coming to the stream from this source were manifold the estimated wastes of a great city like Chicago.

These facts had led to very high estimates in different localities and in different countries in regard to the ratio of dilution that was tolerable in streams; whereas we had at Chicago a lake water charged to its limit with oxygen, in fact surcharged much of the time, so that it was not a case of river pollution in fact ,but a case of contributing a new stream to the Illinois carrying its own standard of purity.

After going over all these matters which I have outlined, I determined the ratio at 20.000 cubic feet of water per minute for each 100,000 inhabitants, as a minimum. The bill as drawn was submitted by the committee to the General Assembly as its report, February 1, 1889, and was passed in May of that year without any amendments whatever as affecting the sanitary provisions of the bill.

I was instructed to remain in Springfield by the Mayor of Chicago, and was eventually left in charge of the measure after the preliminary hearing. I am able to say that every feature of the bill that affected the Illinois Valley was canvassed at great length. In my work for the commission, I had the assistance of a party of men, among others Mr. John Erickson, now City Engineer of Chicago; and we were called upon and did compile everything relating to conditions in the Illinois Valley, and made the best estimates that it was possible to make at that time regarding the effect of this volume of water in the Illinois Valley. And those matters were fully explained.

In order to further safeguard the interests of the Valley, provisions were put into the bill to remove certain dams belonging to the State. A supplemental bill was drawn. I myself drew it at the request of the Valley interests providing for a cession of these dams to the United States, on condition that they should remove the same and change its policy to a deep water policy in conjunction with the water supply from Lake Michigan. In the event of the United States not accepting the same, the canal commissioners were directed to remove the dams whenever the water turned down from Chicago should give an equivalent depth for navigation.

A joint resolution was passed by the General Assembly,

which I prepared by request stating the policy of the State, which was to produce a channel not less than 22 feet deep across the Chicago Divide to Lake Joliet, and not less than 14 feet deep thence to Utica, so fashioned as to permit future increase in depth, and requesting the United States to stop work on the dams at La Grange and Kampsville and enter upon a policy of deepening the Illinois River by dredging, in conjunction with this water supply from Lake Michigan, and produce such depth as might be feasible by such method. This resolution was repeated in 1897, which I also drew by request, and there the proposition is mentioned of 14 feet through the Valley, which is the origin I think of that phrase.

Our examination of the Illinois Valley had determined that 14 feet could be produced by the aid of this water supply; and that by producing such depth of water, this channel would be self-sustaining and not subject to depreciation and would make a better drain for the Valley, and assist in the reclamation of the lands. All these matters were prime factors, as well as another matter which was uppermost in the minds of the State Board of Health and in the minds of the General Assembly, and that was that the solution that served Chicago would likewise serve all the populations that could exist between Chicago and the Mississippi River, by reason of the progressive purification of the sewage, through which it could take on an additional burden from point to point.

After the passage of this bill, the subject matter of a petition for the organization of the Sanitary District was taken up by the Citizens' Association, and I acted as consulting engineer to the petitioners and prepared a number of exhibits which were submitted to a committee of Judges of the Circuit Court, which was provided for by law, who held hearings and entertained objections in respect to the proposed boundaries of the District, and to finally determine the same. These hearings were continued over a number of days, and all interests subject to taxation within and without the proposed district appeared. And it became necessary to develop before this Commission a complete project, to determine you might say a complete project by which the Commission could judge that every part of the territory which it was proposed to tax would be benefited and could be served.

They finally determined the boundaries of the district on the North by the north line of Lake View and Jefferson; on the West, the west line of Cicero, and along the range line through the township of Lyons, including outside thereof

some eight square miles along the Des Plaines River below Riverside; thence easterly along the south line of the Town of Lake and across Hyde Park at 87th street; the same including 185 square miles.

At the time of the passage of the Sanitary District Act, this area was divided up into a number of municipalities. The city of Chicago itself covered 37 square miles and had a population in 1888 of 802,651; the town of Lake View 42,339; Jefferson, 10,622; town of Lake 56,661; Hyde Park north of 87th street 41,000.

All these areas above scheduled were consolidated with the City of Chicago at the general election in 1889 by authority of an act of the General Assembly. There was in addition the town of Cicero, with a population of 13,926 and a part of the township of Lyons with a population of 1,293, and these together aggregated nearly 1,000,000 (988,329). The proposition was voted upon at the general election in November, and the Sanitary District Act was adopted by vote of 70,000 to 200, in round numbers.

In the December immediately following, a special election was held for trustees; and the Board finally organized as a Board of Trustees of the Sanitary District in January, 1890, and elected its officers. I was elected Chief Engineer for the Sanitary District, and entered upon my duties at once. These consisted in bringing together all the data and exhibits that had been prepared during the prior investigations until the Supreme Court decision affirming the validity of the act was handed down on June 12th, 1890.

Q. That was the Nelson and Wilson cases, wasn't it?

A. Yes, sir. Immediately thereafter an engineering force was organized on a large scale and proceeded with the definitive surveys which preceded construction, and the actual carrying out of the work itself.

Q. What plans did you consider then as to the location of the main channel and its adjuncts?

A. At that time, our particular studies and surveys were directed towards locating the main channel and the river diversion from the Chicago River to Joliet, and making all land surveys required in connection with acquiring the right of way; and of course with a view to putting that work under construction as soon as possible.

Later, and in the course of my first term as engineer and trustee of the Sanitary District, we completed comprehensive surveys extending over the entire area of the District and

outside of the same for the purpose of taking up the border definitions on the collateral projects.

The plans except as to details and except as to specific definition had all been practically determined before the law was passed, and were exhibited with all needful detail before the Committee that determined the boundary of the District.

Q. Were any plans considered at that time with reference to the building of an auxiliary channel from the main channel to connect with the little Calumet River?

A. Yes, sir, the plans of that period not only exhibited such a channel but also the Evanston channel. In fact the Calumet proposition was worked up by the preliminary report of the Hering Commission in 1887 and was always regarded as one of the integral parts of the comprehensive plan.

It was further developed or reported upon in 1896-7 by the Intercepting Sewer Commission of the City of Chicago; and also considered at length by the Committee on a comprehensive plan in 1901. I was a member of the Intercepting Sewer Commission and also the Committee on Comprehensive Plan.

Q. Did you consider plans with reference to intercepting sewers for the city of Chicago at that early time?

A. Yes, sir; those were considered from the beginning, and plans were actually made in connection with the disposal schemes in Indiana and in the lake for intercepting the lake shore sewage, and this matter was taken up in final preparation for work by the Intercepting Sewer Commission or what was known as the Pure Water Commission of the City of Chicago in 1896, and definite plans prepared which have since been carried out with some amendments covering the entire city front from 87th street on the south to the northern city limits. There were two of the sewers that discharged into the lake under the old Chesbrough plan, the one at 12th street and the one at 22nd street, and they were actually reversed on or about this time, taken up and reversed.

Q. Prior to September, 1890, did the Sanitary District expend any money in connection with the carrying out of these plans that you have mentioned?

A. The Sanitary District was instituted for the specific purpose of carrying out the projects which were outlined prior to its organization, and had proceeded by that time in the definitive surveys in relation to the main channel from the Chicago River to Joliet. They had also instituted surveys on

the Chicago River with a view to the definitive surveys for its enlargement.

Q. When you became chief engineer in January, 1890, you proceeded immediately to further work upon those plans, did you?

A. Yes, sir.

Q. For the Sanitary District?

A. Yes, sir. There was nothing left to do except to define the things on the ground, practically. The genius of the whole proposition from the outset, held in mind unvaryingly, was to keep the flow of sewage away from Lake Michigan as far around the rim of the lake as was practicable.

Mr. Hopkins: I move that the answer to the question that was started this morning, the long answer, be stricken out for the reasons that have already been assigned, and in particular, in regard to this matter of stipulation, I do not understand that the stipulation covers legislative acts, or purposes and motives of that kind of the legislature. There is no objection to the testimony being secondary because the Journal is not produced, but I object in general to the testimony of intention, motive, purpose, genius.

Mr. Adcock: Q. After December, 1890, when you ceased to be the chief engineer, what work did you take up?

A. I again resumed my connection with the State Board of Health as consulting engineer, with a view of completing the report which had been made in preliminary form in 1889, and putting the whole subject matter of our knowledge of the conditions in the Illinois Valley in proper form for printing and record.

Q. Prior to the organization of the district, were any discussions, had in any engineering society with reference to the probable effect upon lake levels from the diversion provided for and contemplated in the third scheme, third plan of the Drainage Commission?

A. Yes, sir. That subject matter, I was charged with the consideration of, and I virtually incorporated my own findings in the Lakes to the Gulf Waterway discussion published in 1888, January, in regard to the probable effect on lake levels.

That year I was secretary of the Western Society of Engineers, and the subject matter was taken up as a topic for discussion, and a paper prepared and submitted to the Society in September of that year by Mr. George Y. Wisner, father of the present chief engineer of the Sanitary District, in regard to the probable effects of abstracting 10,000 second feet

at Chicago in the proposed Sanitary Canal. There joined in that discussion Mr. D. Farrand Henry of Detroit, a gentleman long connected with the Lake Survey, and who had made all the studies and observations in regard to the discharge of outlets of the lakes up to that time. There also joined in this discussion Mr. William Pearson Judson of Oswego, long connected with Lake Harbor Improvements; Mr. Louis M. Haupt of Philadelphia; Mr. J. B. Johnson of St. Louis, later Dean of the Engineering College at Wisconsin University; Mr. Clemens Herschel of New York, who was regarded as the leading authority in hydraulic engineering in this country, and Mr. Benezette Williams of Chicago. I edited these papers and included my own discussions. They were all printed together in the Journal of the Engineering Society, and were reprinted for distribution by the Citizens' Association of Chicago, and were before the General Assembly before the passage of the law.

Q. Was Mr. Wisner then in the Government service, do you know?

A. He had been. I don't think he was at that time. He had been connected with the Lake Survey, and also with the survey of the Mississippi River and the Illinois River. He made a survey in fact, under Major Benyaurd, between Joliet and La Salle in 1882 and '83.

Q. What is the available water supply of the City of Chicago?

A. No water supply has ever been entertained for the City of Chicago except Lake Michigan, and no other source of water for the city is really feasible, except Lake Michigan. The water supply from all the Great Lakes has been regarded perhaps as superior to any source of water supply elsewhere existing in this country, by reason of the age of its waters, through which all the biologic processes of nature have worked themselves out, those that are in any way detrimental to human kind.

The average flow over Niagara Falls would take one hundred and fifty years to drain out the contents of these lakes, if they were not replenished and in the absence of evaporation. The Chicago Sanitary Canal, if operated at 15,000 second feet, would be supplied for 2,000 years, so the average age of the water of the lakes is 150 years.

There is no possible substitution for these waters, which could equal them in value or efficiency. There is no possible treatment of water which is the equivalent of these aged waters. The matter of age in waters has been given in the

last few years a very great deal of consideration. Mr. Stearns of Boston in the Metropolitan Boston Supply projected a reservoir there and places considerable stress by reason of the fact that the average age of those waters will be 6 to 8 years, and they will have time to whiten and bleach, and work out their biologic cycle.

The same proposition I had up in connection with the Denver water supply where I was intrumental in constructing a reservoir that would carry three years' supply for the City of Denver, and secure the same object.

Q. Is that Mr. Frederic P. Stearns, the gentleman you mentioned?

A. Yes, sir. I might add that the production of the purity of this water supply has been almost a purpose, from the inception of sanitation at Chicago; and absolutely so since the report of 1885.

There is very little land water going into the south end of Lake Michigan; the nearest point of any tributary of considerable size being the mouth of the St. Joe River, more than 60 miles away.

The sanitary project contemplates and has contemplated from the outset extending this divorce between land waters and lake waters as far around the rim of the lake as possible; north to Lake Bluff at least, on the north and east across Lake County in the State of Indiana; and when the proposition is entirely worked out there will be some 60 and 70 miles of the lake shore entirely free from the intrusion of any land water or sewage whatever. And this puts Chicago in a better position in relation to its water supply, and secures for it a better water supply than is provided for perhaps in any city in the world; one that is automatically free from contamination or possibility of contamination.

Q. What was the condition of the pollution of Lake Michigan from 1880 to 1890, and what was the condition of the Chicago River during that period?

A. I have already stated that in part, in discussing the results of an examination made by me in 1886 and '87, respecting the product of decomposition from sewage in the Chicago River. In those years, especially after 1883, the Illinois and Michigan Canal was operated up to a limit of 60,000 feet of water per minute or a thousand feet per second, which was little in excess of the ordinary flow of the sewers coming from the water supply and the ground waters; and the result was that any range of any considerable amount that produced any run-off at all in the sewers or in the water-

sheds outside of the sewerage area produced a flow towards Lake Michigan, which entered the lake water and contaminated the same.

There were also conditions where lake fluctuations produced a similar result. This bobbing of the lake up and down, which I have observed through a range of 18 inches every 20 minutes, had the effect of sending the current up the river, and then set it back again; amounted to a species of milking process, by which the content of the Chicago River was gradually milked out into the lake.

Again, there were other changes; sometimes the lake would be up an extra foot, and all the bad waters would be sent up the slips and the South Fork and North Branch, and fish would attempt to make a trip through the blue waters of the river and the lake would fall as quickly, and all the bad waters would set out into the channel, and we would have large numbers of dead fish in the river and in the canal.

The South Fork was without circulation during this period, and in a malignant condition.

The North Branch had only the nominal circulation created by the Fullerton avenue conduit, which was changed once in about three days and was in a bad condition. Of course in flood time, when there was any considerable amount of water, the contents of the river went out in a most affirmative way into the lake.

I will say, further, that the duration of this positive flow into the lake was variable. Under the conditions of the flood of 1881, it probably was not less than 100 to 120 days; probably in the minimum years not less than 25 or 30 days, but that is an estimate and not a positive determination.

Q. Was there any smell arising from the Chicago River as the result of sewage being turned in there?

A. The smells were affirmative in the North Branch along the main river, and beyond any power to describe the same in the South Fork. In the examination which I made in 1887—1886 rather, I was on the river in a tug for several days dredging every acre of its content to ascertain the character of the deposits on the bottom. These were brought up and spread over a broad table on the fantail of the boat and examined carefully by working them over with a paddle and examining them with a glass, and samples of them taken from time to time for more critical examination. And in my trips up the river, and especially up the South Fork, men were so nauseated that they were unable to take their meals, and

some of them did not recover for a week afterwards their normal condition.

Q. There used to be a saying that a man could walk over the river; there was a scum or something or other arising there?

A. At times there would be a scum, sometimes extending clear across the South Fork, which appeared to be six or eight inches thick, and over which the fowls, geese and duck of that region, proceeded without difficulty. I have never seen anybody walk over it. I have heard of that scum having been afire; and the vessels that went up into those forks lost their white paint very quickly. Some of them that went up there pumped the waters into their boilers for the purpose of taking the scale off their boilers.

There was noticed, however, in the death charts which I prepared in regard to zymotic diseases in Chicago, covering the years 1890, 1891 and 1892, that the deaths from miasmatic or air-breathing diseases seemed to be more prevalent in the region where these bad gases were most intense. And in the inquiries which I made at that time among physicians, it was generally recognized that throat troubles and other air-breathing maladies were more malignant where these emanations were breathed.

Q. Did this pollution of the Lake Michigan water have any effect upon the death rate from typhiod fever and other water-borne diseases?

A. Yes, sir, a very pronounced effect. I investigated a typhoid fever epidemic in Lake View in 1889 for the State Board of Health, and later followed the matter up in 1891. The epidemic that started in Lake View continued with ups and downs through 1890, 1891 and 1892, and then gradually subsided.

In 1891, the death rate in Chicago was 480, I believe, in May of that year, and for the entire year the number of deaths from typhiod as then diagnosed was something over 1,700.

Q. That would be about 170 per 100,000?

A. Estimating the population at 1,000,000 within the city proper, it would be 170 per 100,000.

Q. Did you mention the death rate in Chicago just prior to the establishment of the sewer system, at the time Mr. Chesbrough was brought on here?

A. Yes, sir, 48 to 50 per thousand of population for the years 1849 to 1854, inclusive; about three times the normal to the city since we opened the Drainage Canal.

Q. In making your investigations as to the death rate from

typhoid fever in 1889, 1890, 1891 and 1892, did you examine the health statistics in Chicago?

A. Yes, sir; I sent men to the health records, or to the records at the City Hall, and we went through the entire list of deaths of the year. At that time they were not classifying and printing a classified statement of deaths. We made a card for each name for each location, and then proceeded to spot it out on the map. In that way we made up the charts for the years 1890, 1891 and 1892, for the particular purpose of disclosing that epidemic, and also the relation of other zymotics.

Q. From 1890, when you ceased to become Chief Engineer of the Sanitary District, will you state what was done by the Sanitary District on the work in the building of its main channel and adjuncts and additions thereto?

A. I was elected as trustee, and took office as a trustee in December, 1891, and continued in that position until December, 1895, and during that period we executed the river diversion, a collateral work of the main channel, by which the river was given a course by itself on the west side of the Des Plaines Valley.

Q. That is when you say "river diversion" you refer to the Des Plaines River, do you not?

A. Yes, sir; so as to leave an intermediate strip between the river and the canal, on which we located and built the Drainage Canal.

At the end of 1895, when I left the District, excavation on the Main Channel was about three-fourths actually made or completed. The right of way had all been procured at that time; the contracts for the Main Channel were also arranged before the close of my term as to be completed in November, 1897.

I was Consulting Engineer of the District in 1897, and we were overtaken at that time with a financial stringency, which seriously embarrassed the progress of the work of the District. The work was proceeding faster than the District could get the funds to pay for it, and so the real work on the channel, the Main Channel, which was scheduled to be completed in November, 1897, was not actually completed until about November, 1898, when it was substantially completed, and the District then notified the Governor of that fact and asked for the appointment of a Commission. I think the first action by the Board on that matter was in November, 1898, and the petition actually was transmitted to the Governor in January, 1899, as I recall it.

There was a delay at that time in view of the fact that the state had made no appropriation for the maintenance of this Commission, and the Sanitary District deposited the necessary funds with the State Treasurer, and the Commission proceeded later to perform its functions, and the Sanitary Canal was finally opened on the recommendation of the Commission to the Governor January 17, 1900.

Q. That was when the Governor granted the authority under the terms of the act?

A. Yes, under Section 27 of the act.

Q. The channel was then opened and the water flowed through the Main Channel into the Des Plaines River?

A. Yes, sir, and has been flowing continuously ever since.

Q. Do you remember when the work on the enlargement, the widening and deepening of the Chicago River, was commenced to accommodate the flow contemplated through the main channel of the District?

A. Very elaborate surveys were made of the Chicago River for the purpose of defining the property questions at the place of the enlargement while I was a trustee of the District prior to 1895; and the work of actual enlargement of the river began in 1896.

The United States took jurisdiction of the Chicago River and exercised authority over it for the first time under the clause in the Rivers and Harbors Bill of 1896, and a permit was then issued to the Sanitary District for the improvement of the stream, by the Secretary of War. The stream was prepared for a flow of 300,000 feet of water, the preliminary requirement of the Sanitary District law, some time prior to the opening of the channel.

After the flow of water had been established, in 1900, the Sanitary District then matured plans for enlarging the river for the purpose of getting the larger quantity of water required by the Sanitary District Act, and actually entered upon that proposition in 1900; and the whole subject matter was before the commission on a comprehensive plan of 1901, of which I was a member, and the trustees went to the Legislature and got an enlargement of their bonding power for the purpose of expediting the work in 1901.

I will say in regard to that, the improvement made prior to the opening of the channel was simply preliminary improvement. It was recognized that in order to obtain this flow in the water in the quickest possible time and at the lowest possible expense, it was recognized that there would have to

be a wholesale improvement from the beginning, such as was undertaken in 1900.

Adjourned to Friday, March 6, 1914, at 10:00 o'clock A. M.

Friday, March 6, 1914, 10:00 A. M.

LYMAN E. COOLEY resumed the stand for further direct examination by Mr. Adcock and testified as follows:

Q. I will call your attention, Mr. Cooley, to a resolution passed by the Board of Trustees of the Sanitary District of Chicago on April 21, 1891, appearing in the printed proceedings of the Board as follows:

> "Resolved, That this Board hereby ordains that the Sanitary District of Chicago do forthwith enter upon, use, widen, deepen and improve the Chicago River from its mouth at Lake Michigan to the South Branch thereof, and also the South Branch thereof, together with the South and West Forks thereof, so as to make the same a proper and sufficient supply channel for the Main Channel heretofore surveyed from the Chicago River to Joliet;
>
> And further, that the acting Chief Engineer be and he is hereby directed immediately to investigate and report upon the capacity of said river and its said South Branch and Forks for that purpose; and also as to any changes that should be made therein. And that a copy of this resolution, certified by the Clerk, be forthwith transmitted to the Mayor and Common Council of the City of Chicago and the Secretary of War of the United States."

I will ask you Mr. Cooley what the Sanitary District did pursuant to that ordinance?

A. The Chief Engineer of the District went ahead and made an exhaustive survey of the Chicago River from Robey street to the lake, defining all property rights and cross sections of the stream, with a view to definitive plans for the improvement of the river. And these surveys were completed prior to 1895, while I was on the Board. They were followed by definite plans for the improvement of the river, which were inaugurated in 1896, in co-operation with the United States, which made an appropriation for the improvement of the river in that year; and the river was improved to a depth of 20 feet by dredging the stream. And the bad angles in the stream were cut off, and in some places the river was widened, and in the vicinity of Adams street and Jackson street,

by-passes were constructed at the constricted parts of the river, in that vicinity, for the purpose of giving the preliminary flow required by the Sanitary District law of 300,000 cubic feet at the velocity of 1¼ miles per hour.

These surveys were also used as the basis of the larger improvement which was immediately defined and inaugurated after the opening of the channel in 1900, for a capacity of 10,000 feet per second.

That plan consisted in bascule bridges in the stream of a uniform width of 200 feet, and a central depth of 26 feet; and has also been carried out in part with the co-operation of the United States.

Q. During the period before 1900, the United States improved the river in connection with this work?

A. Yes, sir, from 1896, after there was an appropriation of $700,000 for the improvement of the Chicago River, which was the first appropriation ever made for improvements above Rush street.

Q. What was the capacity of the Main Channel at the Rock Section?

A. The Rock Section was actually 840,000 cubic feet capacity.

Q. That is cubic feet per minute?

A. Per minute, yes, sir.

Q. And after 1900, did the United States make any improvement in the Chicago River?

A. Yes, sir.

Q. At the time that the work was being carried on by the Sanitary District?

A. Yes, sir.

Q. In deepening and widening the river?

A. Yes, sir. They continued their work. There has been appropriated all told something over a million and a quarter of dollars, (expended June 30th, 1911, $1,253,957) as I recall it. I haven't the exact figures at hand, except the first appropriation which was $700,000 in 1896.

Q. What was the occasion for making further improvement in the Chicago River and its branches after 1900 by the Sanitary District?

A. The further occasion was to get the increased capacity which was required with the growth of population, after the initial capacity of 300,000 feet had been established.

Q. Was it to accommodate the maximum flow through the main channel?

A. That was the original intention, to accommodate 600,-

000 feet by way of the Chicago River, and later that was supplemented by the flow by way of the 39th street conduit.

Q. Was that new improvement or the improvement after 1900, known as the Chicago River Improvement Project of 1900?

A. Yes, sir.

Q. That was of the Sanitary District, of course?

A. Yes, sir. I went through all those propositions on the Expert Commission in 1901.

I will state in that connection that the 39th Street proposition was determined prior to 1901, but I do not remember the exact year.

Q. That is the pumping through the 39th Street intake?

A. Yes, sir. They were all part of a general plan for supplying the Main Channel with water in excess of 300,000 feet.

Q. If the flow through the Sanitary District Canal had been limited to 5,000 cubic feet per second after 1900, would it have been necessary for the Sanitary District to have made the changes and alterations in the Chicago River that it subsequently did make after 1900?

A. That is if the law had made that the capacity of the channel?

Q. Yes?

A. No, sir.

(Question read as follows) "If the flow through the Sanitary District Canal had been limited to 5,000 cubic feet per second after 1900, would it have been necessary for the Sanitary District to have made the changes and alterations in the Chicago River that it did make after 1900?

Mr. Hopkins: Necessary for what?

Mr. Adcock: For any purpose; that is to keep the flow down to 1¼ miles, or to make it safe for navigation.

Q. What purpose did you have in mind?

Mr. Adcock: For any purpose.

The Witness: I would like to supply an omission in my answer to the question in regard to conditions existing in Chicago between 1880 and 1890? In the examinations in regard to the deposits from sewage decomposition in the Chicago River, slips and branches, there was no signs of life such as usually accompanies filth production in any portion of the river until we reached the remote heads of slips and at the North Branch and out at the West Fork, where the septic action was limited in amount. In other words the toxins produced in this stream through the decomposition going on

were absolutely destructive to all life except the bacterial life in the waters themselves.

From this condition, and from the conditions of deposits existing in the main sewers of Chicago, it was reasoned at that time that no such things as disease germs reached the lake under low water conditions in the river and in the sewers, but that in flood time the disease germs from the population went to the lake, where they did not encounter this septic condition.

At that time, we had a large population discharging into the lake directly; and I also made examinations at the mouths of sewers on the lake, and opposite these mouths we did find these filth orders of life, which were not destroyed by reason of the septic action and which could exist there in the clay and in the deposits near the mouth of the sewers on the lake.

I wish also to say in that connection that I watched the effluents at that time from the 22nd street sewer and from the 35th street sewer, and have been able to see the same in the Lake, half a mile or more from the shore through the irridescent shimmer as the lake was dancing under a western sun.

At that time also in 1885, they operated occasionally the Fullerton avenue conduit into the lake, and I have seen the effluent going in an unbroken body out into the lake for more than a mile before it was diffused. That was not a usual occurrance but it was an occasional condition. And it would swipe across the crib at times like the tail of a comet and cause an eclipse, you might say, of the pure water which was being pumped through the crib. That was what I should have added yesterday, in completing the answer.

Q. I show you a plan Mr. Cooley marked Exhibit H, to the answer filed in this case entitled "Sketch of Plan for Increasing the Capacity of the South Branch of Chicago River." That was the plan which is attached to the permit of the Secretary of War issued in 1896, or purports to be. Do you know whether that indicates the preliminary improvement which you mentioned?

A. Yes, sir this does. I have seen this plan before.

Q. I also show you a map or plan Exhibit K 1, to the answer filed in this case entitled: "Sanitary District of Chicago, map of the Chicago River, Sheet number 3, from Kinzie street to 18th street; scale 200 feet to an inch," which purports to have been attached to the application made by the Sanitary District for a permit to the Secretary of War dated April 26, 1900, and ask you whether that indicates the plan

for the improvement of the Chicago River under the project of 1900, so far as it goes?

A. I made a critical examination of these plans when I was on the Expert Commission in 1901, and that is the same plans that we examined at that time.

Q. I show you another plan or map which is attached to the answer in this case as Exhibit K2, entitled: "Sanitary District of Chicago, Map of the Chicago River, Sheet number 2, from 18th Street to 31st Street, Scale 200 feet to the inch." This map or plan purports to have been attached to an application made by the Sanitary District to the Secretary of War for a permit dated June 7, 1900. I will ask you whether that map or plan shows the improvement of the Chicago River from 18th Street to 31st Street under the project of 1900 mentioned?

A. It shows the proposition which I reviewed in 1901, when a member of the Expert Commission. It was procured by the District in 1900.

Q. It is stated here that the scale is 200 feet to the inch on both of the maps which are mentioned?

A. That is the original scale of the maps, with which I am personally familiar, and these are photo reductions.

Q. The width of the river under the project to be 200 feet, as I understand it?

A. The width of the river generally was to be 200 feet, with a central depth of 26 feet. That was the minimum general width. There were parts of the river that were 300 feet in width in which no changes were made other than dredging.

Q. Do you know how much money the Sanitary District expended under the preliminary projects which you mentioned, commended in 1896 and finished before the opening of the channel, and also the amount that was expended under the 1900 project?

A. I have compiled those figures in detail from the beginning. The expenditures up to 1913, are as follows:

Total expenditure up to and including 1899,	$ 727,441.02
Expended in 1900,	837,165.39
Total expenditure up to and including 1900,	1,564,606.41
" " five year period, 1901-5,	6,727,708.34
" " up to and including 1905,	8,292,314.75
" " five year period 1906-10,	2,082,229.92
" " up to and including 1910,	10,374,544.67
" " two year period 1911-12,	266,194.85
" " up to and including 1912,	10,640,739.52

Q. Has the old Illinois and Michigan Canal between the upper basin of Joliet and the Chicago River been used since 1908 for navigation purposes?

A. The Drainage Canal was officially substituted by an Act of the Legislature in 1910, although provision was made for that substitution in 1903. The Canal was used for some years after 1903 for navigation, but whether it actually ceased in 1908 I would not be able to say; but since 1910, the Sanitary District Canal has been used as the official channel.

Q. And the Illinois and Michigan Canal has not been used from the points mentioned?

A. No, sir.

Q. Will you state Mr. Cooley how the improvement of the Chicago River, the building of the Main Channel of the Sanitary District and the Sag Channel and the flow of water through the Des Plaines River into the Illinois River, through the Illinois River has benefited or will benefit navigation?

A. The building of the Main Channel and the improvement of the Chicago River which is a part thereof has extended Lake navigation to a depth of 24 feet 36 miles from Lake Michigan and within a mile or two of the city of Joliet. Lake navigation has not yet developed on a scale of 24 feet, but is predicated for that depth by the new lock now under construction at Sault Ste. Marie.

Below the water power station at Lockport, navigation is extended by a lock constructed by the Sanitary District suitable for small boats down to Dam Number 1, at Joliet 2.6 miles; and this channel is 20 feet or more in depth for most of the distance, and a limited depth of 10 feet after it reaches the Des Plaines River and the upper basin at Joliet. Navigation by small craft can extend to Dam Number 1, at Joliet.

The Sag Channel is of smaller dimensions than the Main Channel, and is available for barge navigation of any draft of barge which can pass under the bridges, such as has been repeatedly recommended by federal engineers, in connection with the route between here and the Mississippi.

At the end of the Main Channel near the power station, 36 miles from Lake Michigan, a location has been reserved for a lock of any dimensions that may be necessary or desired, by which the depths and capacity of the Main Channel can be extended down the Des Plaines River by future improvements thereof.

The jurisdiction of the Sanitary District, so far as producing channels for navigation is concerned stops at the upper basin at Joliet. The state has projected from the end of the Sanitary Canal at Lockport at the waterpower station, under the report of the Internal Improvement Commission in 1907, and by virtue of the constitutional amendment adopted in 1908, a project by which the navigable depth available in the Drainage Canal can be extended to Utica over the rock bound section and the high declivities of the upper Illinois River by means of five locks and four dams and the development of the pools between these dams. This project proceeds on the basis of 24 feet to the second lock at the head of Lake Joliet through the city of Joliet, where it is largely in rock cut. But from that point, the head of Lake Joliet to Utica, it proceeds on the basis of a preliminary depth of 14 feet, to be deepened progressively as the needs of navigation shall require.

Further than that, there has been no actual legislative provision as far as the state is concerned. The state has expressed its policy in a number of resolutions and statutes, and the United States has been asked to co-operate to the extent of building the locks in that part of the river, under the constitutional amendment, between the water power station at Lockport and Utica, at a cost of about eight millions of dollars, and to make the improvement by dredging in an open channel in the Illinois River between Utica and the mouth of the Illinois River, a distance of 230 miles; and there provide a channel of a preliminary depth of 14 feet, at a cost of about $8,000,000.

In other words the proposition as it now stands is this: That the state of Illinois by the Act of 1889, makes the Main Channel of the Sanitary District to the upper basin a navigable stream and gives the United States control of it when-

ever the river shall be improved below, and the Sanitary District has expended upon that and collateral works something like $80,000,000, and the state of Illinois has put itself in position by act of the Assembly, to spend an additional $20,000,000 in extending, a total of about $100,000,000. And the United States has been asked to co-operate to the extent of providing $16,000,000; the effect of it all being to produce a waterway from Lake Michigan 327 miles long to the Mississippi River at Grafton, with all structures, and rock cuts in the same channel for a depth of 24 feet and a preliminary depth of 14 feet in the river below the head of Lake Joliet.

Perhaps I may add in that connection that in the later consideration of the matter by the State after 1907, it is based on a flow of 14,000 second feet; and that the Deep Water Project is not practicable without the aid of the large water supply from Lake Michigan, which has been authorized by the State Law.

Outside of that, we would be limited to 8 or 9 feet as the best that could be done.

Q. This flow of water through the Sanitary District Channel, the maximum amount would be necessary for the improvements in the navigation of the Illinois River and the Des Plaines River which you just mentioned?

A. These depths of 14 feet were predicated by the original act and collateral legislation in 1889, and in all subsequent legislation, were based on a flow of 10,000 feet and the report of 1907 used that depth of 14 feet as a preliminary depth, but states that with the aid of the 14,000 feet, it will be possible to continue 24 feet to the city of Peoria and 20 feet more or less from thence to the mouth of the river.

And I assume from the fact that the constitutional amendment was based on that report, that is the project. It is the one that has been advocated by the Lakes to the Gulf Deep Waterways Association, and the one that was presented to Congress in the hearings of 1910, before the House Committee and before the Senate Committee, and Congress made conditional appropriation of a million dollars for the beginning of work, whenever an understanding should be reached with the State of Illinois regarding a plan of co-operation.

Q. How much greater width and depth has been provided by the improvement made by the Sanitary District in the Chicago River and its branches?

A. The Chicago River prior to this improvement was little more than an adaptation of the Chicago Creek, which

was known before Chicago was here; and its capacity for carrying a flow of water was limited. It is difficult to make a comparison where the stream was so little adapted to the present purpose, and where the change has been so radical.

Originally the Chicago Creek carried 12 feet up to the Forks, and its original improvement, the first improvement, was based on a depth of 13 feet, which was subsequently increased to 16, and the tunnels built under the river limited the use of the Chicago River to 16 feet, until they were removed within a comparatively recent period. They were removed by the city at a very considerable cost, which should be added to the expenditure of the Sanitary District and the United States, in getting at the true cost of the improvement of the Chicago River.

Q. When the Sanitary District entered upon the improvement of the Chicago River, it was approximately 16 feet in depth?

A. Yes, sir.

Q. The depth has been increased to approximately 26 feet?

A. It has been increased approximately to 26 feet.

Q. And that is the depth carried through the main channel, through the power house?

A. 24 feet.

Q. 24 feet?

A. Yes.

Q. And the river has been widened from an average width of approximately 100 feet to—

A. There were portions of the river that would run up to 200 feet and even 300, and again other portions that were less than 100. The narrow portions have been widened, or are being widened, except a very limited area near the Pennsylvania Central Station, which has been greatly delayed.

Q. It has been widened to a large extent throughout its entire length, the Chicago River and the South Branch?

A. Yes, sir, so much so that it could almost be considered a new river.

Q. Now with reference to the bridges, when the Sanitary District started to improve the river, they had the old center pier bridges mainly, did they not, in the river?

A. Yes, sir.

Q. And those center pier bridges have been replaced by lift bridges, leaving the channel free for navigation purposes and so forth, have they not?

A. There were center pier bridges with openings varying

all the way from 60 feet up depending on the width of the river; and the openings have now all been made uniformly 140 feet or more, so that vessels can go down the center of the stream without interfering with vessels that are moored at the docks, whereas formerly with the old type of bridge, they had to crowd the dock line making it unavailable, in order to pass through.

Q. Has this increase of depth and width of the river and the changing of the bridges been of benefit to navigation upon that river?

A. It has been of very great benefit. Under former conditions the river in many places was so constructed and tortuous that boats of the model prevailing along in 1900, 476 feet in length or thereabouts, were unable to pass through the river.

Since then, we have had boats up to 617 feet in length which could pass through. The alignment has been corrected and the channel deepened to a limit of 26 feet for a width of 140 feet in the center and the bridges have been put in with that central opening, so that the river is now available for a type of vessels which could not be considered in the early history of the stream and up to 1900.

Q. Now, has there been any increase in the depth of water in the Des Plaines and Illinois River, by virtue of the flow through the Drainage Channel?

A. There has been a very substantial and material increase in the depths. The lock and dam system built by the State between LaSalle and Havana provided for a depth of 6 feet on the mitre sills at low water of the Illinois River, and this low water has shrunk at times down to limits of 400 and 500 feet per second within the division that I am speaking of. The present flow of the Sanitary District would give 6 feet throughout all that reach above the plans of the old low water, to which you could add 20 inches for the depth existing under original low water. In other words you would have 7½ feet under the natural conditions in the river between those points without the dams.

The Board of Engineers known as the Ernst Board, which reported in 1905, stated that with a flow of 4200 second feet it would be possible to obtain in the Illinois River a navigation considerably in excess of 7 feet, without the aid of any dams whatever, and that there should be no objection to the removal of these dams.

It was examinations of these questions which led to the

project of the state for an open river improvement in these parts without the aid of the dams.

The estimates which were made at that time, made largely by me and my assistants have proven to be conservative, and that we can obtain better navigation without the dams than we had supposed when the state fixed its policy in that matter; and that we can obtain the 14 feet more readily than supposed, and obtain the 24 feet and the 20 feet which I mentioned above and below Peoria more readily than supposed.

Q. When you speak of dams, you refer to the two state dams?

A. I refer to the state dams.

Q. At what points are they?

A. At Henry and Copperas Creek; and the federal dams at LaGrange and Kampsville.

Q. The state dams were completed when?

A. The state dam at Henry was opened in 1871. The state dam at Copperas Creek was opened in 1877.

The federal dam at LaGrange was opened in 1889 and the federal dam at Kampsville was opened in 1893. They were all part of a project that goes back to 1866 and '67.

Q. There are locks at each of these dams are there?

A. There are locks at each of these dams.

Q. Before the Sanitary District flow was established through there, it was necessary for the boats to pass through these locks?

A. At low water and at ordinary stages of the river, boats used the locks. At high water they passed over the dams without obstructions.

Q. I presume the principal navigation was carried on in the summer time when the water was at ordinary stages?

A. Yes, sir, summer and fall months.

Q. Is it any benefit to navigation not to be compelled to use dams of that kind, or locks, I mean?

A. A very great benefit on account of delays; on account of tolls charged at the state dam, though there is no charge at the federal dam, and by reason of the fact that the capacity of the locks is limited and boats and barges and fleets have to be accommodated to the size of the locks. Boats without the dams today would come to LaSalle, and barge fleets would be made up there. They would not pass through the locks if the dams were absent.

Q. Does the Sanitary District own property on each side

of its main channel available for docks and dockage purposes?

A. The Sanitary District has an estate between Robey Street and Lake Joliet of between seven and eight thousand acres; and under the law is permitted to develop dockage and utilize this property.

Q. This property that the Sanitary District owns is adjacent to the channel and along the channel its entire length isn't it on both sides?

A. Yes, sir, it was obtained for the purpose of facilitating the construction of the channel and the river diversion.

Q. Of what benefit are these dockage rights and privileges to navigation?

A. Taking the channel at 30 miles from Robey Street, it really adds to the capacity of the Chicago Harbor and its potential value about 60 miles of dockage; and if the estate is developed further by slips, why the amount of dockage that can be thus developed is unlimited.

Q. It is capable of being developed by slips, isn't it?

A. It is so, yes, sir.

Q. So that it would be possible to establish practically an inner harbor?

A. Yes, sir.

Q. In Chicago, for commercial purposes and other purposes for Chicago?

A. Yes, sir. That is one of the propositions that has been held in view from the beginning, and was outlined in a report which I prepared in 1890, printed in 1891, that the Drainage Canal on its waterway site would be developed as an auxiliary to the Chicago Harbor, and that future industrial development would largely take place, by a natural evolution as the city expanded, alongside and down this channel into the state; and that that view of the proposition was in harmony with sound public policy, as these growing industries with their wastes would thus be automatically cared for in the simplest and cheapest manner. So it had a double reason, both commercial and sanitary, for the development of a harbor and its appurtenances in that direction.

That was one of the reasons why the item was put in the bill permitting the district to develop that as incidental to its other purposes. In fact it was the view held in constructing these works that all collateral advantages should be utilized; all by-products that were possible should be created, with a view of mitigating the heavy tax burdens of the community.

And I think that the Chicago Project in its entirety, involving the waterways and dockage and waterpowers and other things that it does is really the first example that we have in this country of a well considered, scientific project of conservation, for all the collateral utilities are to be developed and utilized.

Q. Does the Belt Railroad cross the canal, the main channel?

A. The Chicago & Western Indiana, which is the main Belt Road, crosses the channel near the city limits, between Robey Street and Summit. And the Calumet Terminal, which is also a Belt Road crosses the channel a mile below Summit. And furthermore the E. J. & E., which is the Outer Belt Line, crosses our channel between the water power station and Joliet; and makes the channel accessible to the entire railway system. And in that connection, it may be remarked that the report of the Federal Officer at this point recommends the development of a certain amount of harbor facilities adjacent to the channel, in the vicinity of Summit.

Q. These Belt Roads which you mentioned make it possible to bring all kinds of freight down to the Main Channel?

A. Yes, sir.

Q. And makes it possible, if the channel is developed as you have indicated, to have arrangements for the interchange of lake and rail freight?

A. Yes, sir. In my judgment the location of the Sanitary Canal is really the only practical and economical location for such an interchange about Chicago, the logical place for it to occur. It is centrally located with reference to our commercial facilities by rail. It is accessible directly by a number of the trunk lines, and this number is so large that it practically would do away with the switching charge for all the other lines and we would be rid of $5 to $8 per car on all reshipment business done at Chicago as at present.

On the other hand such facilities transferred more remotely to the south or north would subject the commerce of Chicago to that extra burden.

Q. The Calumet Sag Channel runs from the Main Channel at Sag, Illinois to the Little Calumet River does it at Blue Island?

A. Yes, sir, something over 16 miles long from the mouth of Stoney Creek, at its junction with the Calumet River to Sag Station; about 17 miles from the beginning of the Sanitary

Canal at Robey Street, and about 13 miles above the power station at Lockport.

It runs through a natural depression or valley called the Sag Valley, which is only less adapted to the development of a channel than the territory along the main channel of the District. This route has always been regarded as a favorite route in official reports of the United States, and has been frequently recommended for development for purposes of navigation.

Q. Has the United States taken any steps towards the improvement of the Little Calumet River for navigation up to the point where the Sag Channel will connect with the Little Calumet?

A. It has. The Calumet River is already improved for a width of 200 feet and a depth of 20 feet up to what is called the forks or outlet of the Calumet Lake; and in the last Rivers and Harbors Bill, there was an item calling for a project for the improvement of the river up to Blue Island.

Q. And that is the point at Blue Island where the Sanitary District Channel connects with the Little Calumet?

A. Yes, sir.

Q. That is the Sag Channel?

A. Yes, sir, and the Sanitary District in that connection has been called upon to express its intention in connection with such improvement.

Q. Under the plans laid out by the District, there will be free navigation into the Sag Channel from the Little Calumet River?

A. There will be, yes, sir.

Q. And free navigation from the Sag Channel into the Main Channel of the District?

A. Yes, sir. There is a lock provided for in the statute near the Calumet River, which is wholly unnecessary, and I presume that will be eliminated. At the same time, it will have sufficient capacity to accommodate anything that will go through.

Q. And boats would pass through the Little Calumet River under the improvement project of the United States Government in the Little Calumet River from the Forks to that point?

A. Any boats that would pass through would be able to pass through the Sag Channel, where it has a depth of 20 feet the same as the improvement of the Calumet River. Meanwhile, craft can all pass up this route to Blue Island. It only requires deepening to adapt it to deeper navigation.

There will be no limitation on the capacity of boats passing through except the bridges.

Q. Will navigation be aided or injuriously affected by the construction of this Calumet-Sag Channel, under the plans which the Sanitary District has adopted, and under which it is now being constructed?

A. It will be greatly aided. I think that fact is recognized by official authority.

Q. Has the flow of water through the Main Channel of the District, through the Des Plaines River and the Illinois River been of any benefit from the standpoint of sanitary conditions in the Illinois River and the increase of the fish industry; and will it be of any benefit as the flow increases pursuant to the increase of population within the limits of the Sanitary District?

A. The flow of water has been and will be of enormous benefit to the Illinois Valley for two reasons; the first of which relates to sanitary conditions and the other of which relates to the physical conditions attending upon the river itself, and the overflow lands.

In a condition of nature, the Illinois River had in dry seasons an extremely small volume, which was measured in 1867 as low as 633 second feet. The reclamation of the swamps, which constituted 1/3 to 1/2 of the drainage in some watersheds and the tillage of the uplands has greatly reduced the low water supply and greatly increased the load of detritus which the stream has to carry.

The Illinois watershed is also one of the richest watersheds of the United States in proportion to its area, and produces thereby an enormous vegetable growth which quite consumes the water supply that falls in the growing season, leaving practically nothing to run into the streams. It happens by reason of these conditions that the stream is incapable of taking on any considerable load of sewage from the cities and towns located along its banks.

Further the stream bed is rapidly depreciating on account of the detritus from the uplands. These conditions at times under an ice cover when the organic matters in the water depleted the oxygen supply resulted in the decimation of the fish crop. Nevertheless, even prior to the opening of the Drainage Canal, by reason of the use of the river as an outfall for Chicago sewage and the very considerable increase in the low water volume which was doubled by the canal, even the old Illinois and Michigan Canal in low water seasons in

the upper half of the river, this fish crop had grown to large proportions, reaching from six to eleven and even 14,000,000 pounds; and was the best fresh water fishery in the United States, but was not a reliable industry.

With the accession of waters, the occasional decimation of fish due to an ice cover and the exhaustion of the oxygen supply, and also through the summer floods which came to the river sometimes from this rich vegetable cover, like an infusion of tea entirely devoid of oxygen, which has also destroyed fish life there,—I say by reason of the introduction of the water from the Sanitary District in comparatively large volume multiplied the low water supply at LaSalle by ten times, the low water supply in the lower river by six or seven times, and by reason thereof the fish crop became a reliable industry and has reached a magnitude under the census of 1908 of about 46,000,000 of pounds, of all kinds. And the value to the fishermen had reached over $800,000, and double that to the consumers. This crop represented $10 per acre on all the water space of the Illinois River Valley, or has been otherwise expressed, that the annual output was equal to 50 cents a lineal foot for the river.

Some idea of the magnitude and importance of this industry may be gathered from the fact that the output of this single stream represents ten per cent. of all the fresh water fisheries of the United States, 30 per cent. of all the fisheries of the Mississippi Valley, and is equal to 25 per cent of the entire fish output of the Great Lakes.

I think it is a fair assumption, and is so regarded by our Fish Commission, and by the Natural History Survey of Illinois, that this fish crop is largely due to the use of the stream for sewage disposal. The plankton in the Illinois River at Havanna, which is the basis of fish food, have been under examination by the Natural History Survey of this state since 1894; and since the introduction of the water in 1900, they recognize that the plankton have increased about from two to three times per cubic foot of water. And in view of the fact that the average flow of the stream has or will be doubled at Peoria when the channel is operated to a capacity of 10,000 second feet, the plankton content of the Valley will be increased from four to six times, and the fish crop stimulated proportionately, so that it is likely to grow to far larger proportions than even the present output.

This matter of the fertilization of waters is a new thought to people who have not considered the matter, but has been practiced from time immemorial in the fish culture in China,

and is a recognized method of producing fish products as much as fertilization of land in the older countries, in the oriental countries.

On the other side of the question, in regard to the physical conditions in the Illinois River, we have below Utica a stream 230 miles long with only 28 feet fall, or less than an inch and a half to the mile. The upper half of the stream, down to Havanna, has less than an inch per mile. There are conditions in the Mississippi River when if the Illinois River were low, flood waters would set back clear to Utica, and the stream would be level. There are other conditions in which the Illinois River might be assumed to be in flood and the Mississippi River low, in which the slopes would be doubled.

These conditions make the reclamation of the bottom lands extremely difficult and the maintenance of the river itself as a drain under the increasing load of detritus also extremely difficult. The only salvation, and that has been recognized from the beginning of this project, for the lower Illinois Valley is to introduce into that stream a large supply of water, to remove the dams and deepen the stream by dredging so as to maintain a channel of a good depth with a positive current that will be self scouring.

That condition cannot be produced in nature because the heavy flows in the Illinois correspond more or less closely with the heavy flows in the Mississippi, and with a large supply of water introduced into the Illinois River when the Mississippi is low, we can maintain a scouring channel; and the presence of the dams in that river is not consistent with maintaining such a channel.

Some recent examinations which I have made respecting conditions in the Illinois River show that since the state dams were erected at Henry and at Copperas Creek, there has been a depreciation on the upper half of the river of 2½ feet in the depth of the water below the original low water line of 1867, as it was defined in that survey. In other words, the river bed below low water has shrunk already, between the surveys of 1867 and the Ernst Board surveys of 1903, by 30 per cent.; and the bank-full capacity of the stream has diminished by 15 to 20 per cent.

Further examination of the stream lower down shows that the federal dams have been instrumental in contributing to the depreciation of that portion of the stream, and as I have stated, the only remedy is to make a better drain of the Illinois by deepening it, without the dams, and introducing therein a positive and a large flow of water.

This is important, not only from the standpoint of maintaining navigation automatically, as it were, without maintenance from year to year; but is of absolute necessity from the standpoint of conservation in the reclamation of the bottom lands themselves, of which there are some 400,000 acres between Utica and the Mississippi River. So from this standpoint, not only the interests of sanitation, the interests of the salubriety of the Valley itself, which will become a morass if present conditions continue or if the natural conditions continue, but also in the interest of reclamation of the bottom lands, a deep channel with a sufficient supply of water to maintain a scouring current therein is an absolute necessity.

On the sanitary side, as respects the disposal of sewage in this stream, such disposal was intolerable under natural conditions of flow, practically impossible by reason of the fact already stated, that the waters are already highly charged with organic matter from the very rich watershed, and particularly in flood times more than in low water.

I have seen, when I was examining the river for the State Board of Health, the output at Peoria alone, and at Pekin, from the wastes of the population and the wastes of the industries at those points, produce a black water through which fish could not pass, all the way down to the Copperas Creek Dam, a distance of 25 miles, when the river resumed its normal appearance.

This was significant, not only as to the ease with which the industries and the limited population polluted the stream in its natural condition, but was also very significant in regard to the progressive purification of the stream, even with that limited volume of water.

It was a material consideration in the Legislation of 1889, not only from the standpoint of the State Board of Health but also from the standpoint of all the Valley cities that this water which served Chicago would through its progressive purification be able to serve also all the future population that might exist in the Illinois Valley in urban communities; and that in making a provision here as we did actually make for a population of over 4,000,000, we could assume at least that that would care for an additional future population in the Valley of 1,000,000. So that the Sanitary problem, from the state's point of view and the forces that prayed in the legislation of 1889 was a mutual problem, not only for Chicago but also for the Illinois Valley; the two representing over 70 per cent. of the urban population of the entire state. To deprive them of this water would force all the towns in the Val-

ley adjacent to the Des Plaines and Illinois Rivers to resort to artificial treatment, at very large cost, whereas their problems are now cared for automatically and without cost to themselves.

Q. Is the problem presented of the disposal of sewage of a large metropolitan population like Chicago and its environs, which is included within the limits of the Sanitary District of Chicago, different from the problem presented in the disposition of the sewage of a small city? If there is a difference, will you state that difference?

A. There is a material difference.

Q. State briefly what that difference is?

A. In small cities, they are not endowed usually with the industries of the great towns nor are their sewage wastes disposed of to the same extent by the sewer system as is necessitated in the large cities.

Again, in large cities, dimensions and magnitudes increase with the distances that have to be covered, so that the cost of any solution increases faster than the relative population, than the growth of population; or is out of proportion, you might say, to the growth of population, as compared to the small town or to the average small city, rather.

Q. What can you say as to the advisability of removing sewage so that neither an effluent nor the raw sewage nor the rain drainage from streets, etc., would reach the water supply of the city?

A. I should say that that is the very purpose to be attained with the greatest degree that it is practicable to do so. Fortunately, here, we can reach an ideal limit in that respect.

Q. What reasons have you for the conclusion stated, Mr. Cooley, applying your reasons to the conditions here at Chicago?

A. Any proposition that does not absolutely exclude sewage and land waters from the water supply is unsafe, by reason of the fact that no process of artificial treatment as now advocated, or of filtration of water supplies, gives immunity from any pathogenic germs that may be in the water; and by reason of the fact that any laxity in management or care is liable to bring about contaminations of the water supplies upon which the people may be relying as entirely safe.

I do not regard any proposition in connection with a water supply as safe, that is not automatic, and that depends upon human agencies and solicitude, under the civil service conditions that prevail in American cities.

The Chicago water supply, on the other hand, can be made

absolutely automatic and absolutely free from contamination, and the disposal of sewage can be put on the same basis, so that we can go away and forget about it; have no fear as to the consequences.

Q. It will always work?

A. Yes, sir.

Q. And does not depend upon the action of any person?

A. It depends upon the action of no person; does not depend upon the whims of an appropriation bill, or anybody's action as to whether they are exercising more care and vigilance than is necessary, or any of those things,—human frailties, it is free from. And experience has abundantly demonstrated that whereas in the early stages of these artificial methods much was expected of them in the way of absolutely arresting germ life that was deleterious to health; on the contrary none of them are quite safe. Filters and bacterial beds may get seeded down with the wrong kind of germs, so that the water supplies have to be watched with extreme care.

I think the best illustration of that is the recent report on the Milwaukee conditions by a Board of Engineers that is partial to artificial treatment, where they gather up the supply at the southern limits of the city, and after treatment pump it out into the lake as far south from the water supply as practicable. Then after doing this, they have to provide artificial methods for circulating the waters in the rivers in order that they shall not become offensive; and after going to all this cost, they find that it is necessary to filter the water supply. And then they proceed to say that filtration methods, and slow sand filtration is so uncertain that it will be necessary to watch the results very carefully, and to be prepared at all times to doctor the water with chlorine or some other preparation to kill any germ life that may escape the filters.

I think that probably is as severe a comment as could be made respecting conditions as they have been worked out for other cities not so fortunately situated as Chicago.

Q. How is the city of Chicago located as compared with other cities around the Great Lakes so that its sewage may be removed from its water supply, any effluent, raw sewage or rain drainage coming from streets or the surface of the ground?

A. It is the only city situated about the Great Lakes in which sewage disposal can be made through the back lots, and in which even storm waters for long distances along the Lake Shore may be absolutely excluded from the lake itself, the source of water supply. The pass that we have to cut down

to divert our waters to the southwestward are only 7 to 8 feet as measured by the rock floor at Lemont above the low water of 1847; and only 2 to 3 feet above the high water of 1838, so that a channel can be cut in that direction at a minimum cost.

On the other hand, the lowest divide to the East between the waters of the lakes and the Ohio River is the Wabash-Maumee Divide at Ft. Wayne, which is about 190 feet above Lake Erie. And on the north is the Fox-Wisconsin Divide at Portage, Wisconsin, between the Fox River that empties into Green Bay and the Wisconsin River which empties into the Mississippi River, and this divide is 210 feet above the lake. So it is not possible at any other point about the Great Lakes to make a solution at all similar to that which has been provided at Chicago.

It is one of the endowments of our site, and it is the reason we are here, and it is the reason that the city is here; and from my point of view we are entitled to avail ourselves of it like any other bounty of nature, and to utilize the lakes in that connection.

Q. You are speaking of that from the conservation standpoint, Mr. Cooley?

A. Yes, sir, utilize the lakes in that connection for all the utilities that can be worked out of it. It is perhaps the highest conservation to which waters have ever been put in the world.

Mr. Hopkins: I move that part of the answer as to the point of view be stricken out, as a conclusion.

Mr. Adcock: Q. Mr. Cooley, you have spoken of certain artificial methods of disposing of sewage which were considered in 1890. Will you state the history of these various methods that have been proposed, the condition of the art of artificially purifying the sewage as it exists at the present time, and the efficiency of the various methods of sewage disposal which have been suggested, as compared with the method adopted by the Sanitary District for the disposal of the sewage of Chicago and its environments?

Recess to 2:00 P. M.

After Recess 2:00 P. M.

LYMAN E. COOLEY testified further as follows:

Q. (Last question read.)

A. The investigations of the Sanitary District and of the State Board of Health in 1885 to 1890 considered a number

of propositions which were then seriously advocated as alternatives, and which are now regarded as obsolete.

The matter of land disposal, which is the most effective of all these methods is usually regarded as prohibitive on account of the cost, and because it can only be resorted to in favorable localities; and it is now recognized that if the effluents are to be disposed of in streams where water is used for water supply, that even in this case they must be sterilized. That was one of the principal methods advocated in 1886 and 87 as an alternative.

The other of lake disposal would not now be considered, even with sterilization, as a proper solution under conditions where it was humanly possible to do anything else. The objections are that sterilizing methods are subject to all the human limitations involved in the management of other methods, and are liable to be inefficient; sterilizing fluids are not considered as particularly conducive to public health and that even after sterilization the decompositions go on; there would be a tremendous pollution of the lake bottom, which would be a nidus in which deleterious germs might reproduce at a later period. And in a condition of stirring up of the lake bottom by wings, would make a very unwholesome looking water, if it was not actually dangerous to the health.

As applied at Milwaukee, as I have already remarked, they do not consider it, even with chemical treatment, to be a tolerable treatment without also at the same time filtering the water supply, and even after that sterilizing the water supply, after it had been filtered, when dangerous conditions appear in such filtration effluents.

It is recognized that disease germs will pass through even filters that are used for the purification of waters that are not contaminated with sewage. Unhappily, they get seeded down at times with the wrong kinds of germs.

The third method which was considered but not reported upon, but however was much advocated at that time and appeared in bills before the general assembly for consideration as alternatives were the methods of chemical treatment. The principal one of these was the scheme of Gordon H. Knott, which was endorsed by very influential men, including some engineers from Chicago, which contemplated a tunnel 20 feet in diameter to extend down to Joliet and there the sewage was to be treated and released to the Des Plaines River. The tunnel which was then projected would carry something like 1,000 feet of water per second, barely more than the present water supply of this city. It would not solve any of the other

problems associated with the good health of the city; and the treatment of the sewage proposed by chemical means only removes from 30 to 40 or 50 per cent depending upon the character of the putrescible matter; so that the effluent somewhat stableized would still go to the Des Plaines and Illinois Rivers, and in the known high condition of the organic matters contributed from the land would produce an intolerable condition and be an impossible solution.

The fourth method which has found advocates and was mentioned as an alternative in the St. Louis case is the method by septic tanks, which was developed however after our consideration here at Chicago. Abroad, it was known as the Cameron Tank Proposition, and originally contemplated decompositions without a supply of oxygen, or aeration, known as anaerobic, to be alternated with aerobic decomposition, or the presence of oxygen.

This is in effect the cess pool method, which through various appliances, or in the use of euphonious names is called a septic tank proposition. Everybody is familiar with the cess pool proposition as it existed before we had any method of sewage treatment, or any sanitary science, or where in the country sanitary provisions have not been adopted according to the modern method. But it seemed to have taken on a highly scientific value when proposed by wholesale, in the minds of its advocates.

That was, to my mind, effectually disposed of at Chicago, so effectively that it ought never to have been advocated by anyone, because we had a septic tank on the largest scale possible in this world in the 64 acres of the South Fork; and we had it in the North Branch in an area of more than 100 acres, and the conditions produced were so totally intolerable and inadmissible that it always seemed to me an impossible method of solution for any considerable body of people.

There have been a number of works even in this state and in Indiana constructed on that plan, 10 or 12 I think. I believe to-day there are onlv two of them in actual operation. So that method may be considered as having passed into disuse or having become obsolete, and it should never have been considered, in my opinion, in view of the conditions that were patent here at Chicago.

The later methods were an evolution from the experiments at Lawrence, in a large degree, and consisted of bacteria beds; first, what was known as the contact beds, consisting of a bed of stone in a tank, from 6 to 9 feet deep, which was charged

with sewage a number of times each day, and it was in fact a bacteriological stock farm on a concentrated scale.

The anaerobic decomposition was supposed to occur while the bed was filled with sewage, and then the water was allowed to drain out and was supposed to give place to the aerobic decomposition, and this was much practiced up to a recent time, but is now considered obsolete, or not exactly obsolete but is discarded for a method considered to be superior, which is the percolating beds, so called sprinkling filters, which also consist of a bed of stone or other material; is also a bacteriological stock farm, and in which the decompositions are entirely aerobic, except that it is usually recommended that some sedimentation be given in advance and a slight septic condition produced by 10 to 12 hours in the tank before it goes on to the bed. That is the last remnant of the septic tank proposition.

This method is the only alternative, a survival of all the experimental methods that have been tried out in the last forty years, and it may be said that no alternative that has ever been suggested for Chicago up to this time has proven up in practice, even for a moderate sized city, much less a city of this magnitude.

The method of nature in the percolating filter proposition, in fact in all methods that are practiced is the oxidation method, precisely the reactions which occur by dilution except in the dilution method the gases are absorbed and the operation is without offense; and the danger from the passage of pathogenic forms is probably much less.

All these methods in early times and up to a very recent time were presumed to dispose of the pathogenic germs, but it is now recognized that even the percolating filter does not do that, and that it must be followed by sterilization if the effluent is to be put into any possible source of water supply.

In regard to the chemical treatment, that is practiced still to a limited extent in the outfalls at Manchester and at London, for the purpose of getting rid quickly of a certain unstable element in the sewage, which they throw down as sludge. In the case of London, this sludge is put into tank boats and 7200 tons a day are taken out and dumped into the Sea.

In the case at Manchester, they carry on their purification by bacteria beds and chemical means; mostly by bacteria beds, and remove the sludge to the Sea, in order to save the conditions in the Manchester Ship Canal as far as possible from becoming a nuisance. And they even go so far as to purify the storm water and run that through beds also. I went over the Manchester Canal in the autumn of 1909, when the tem-

peratures were moderate and rode from Salford down to Liverpool on a sludge boat that was taking out a cargo of sludge to Sea, and the Manchester Canal, with all the efforts made in the communities about the Manchester Ship Canal, to purify the sewage outflow before it was put into the canal, was not what I would call in a tolerable condition at all. So that what they consider a measure of success over there in regard to the purification of sewage, I do not think would be looked upon here as a tolerable condition.

(The question pending was here read to the witness.)

The Witness: I will say that in regard to the subject of efficiency, there is no method at the present time available that can compare in efficiency with the method which we have adopted here at Chicago; and there is no alternative which could be adopted which would give us a water supply of any character approaching that which we may enjoy in connection with the dilution method.

I would say further that all these artificial methods are very costly in operation and maintenance, whereas the method here is automatic in action.

I will say further that with the possible exception of Berlin none of these methods make any returns against operating expenses, and even in the case of Berlin it is contributory rather than in any sense a profitable investment, whereas in our case I look upon the conduct of the sewage effluent and its purification on its way to the Illinois Valley as having produced the most successful and profitable sewage farm that has been produced in the world, to the fish product in the Illinois Valley; and that we have really here the only tried out and completely successful proposition in the world.

At the time that we proposed the Chicago proposition, it was looked upon by a large part of the sanitary and scientific world, who admitted their own superior achievements and attainments, as a barbarous one. I think the sentiment in that respect throughout the world has radically changed, and that dilution methods are now regarded as the best and the proper method wherever water supplies are adequate for such a purpose.

I wish to add to that, as a tribute to our own foresight and sagacity, that we are as far ahead today of the other parts of the United States and the rest of the world in regard to this subject of sanitary treatment as we were when Mr. Chesbrough projected the sewer system in 1855. And I believe if we had been able—this I consider very unfortunate for Chi-

cago—to have worked out all the results and made a record such as should have been made of the investigations that preceded and accompanied this work that it would have been regarded as a monumental achievement and revolutionary of the whole thought of sanitary engineering at the time; and would have changed the public thought, scientific thought in the matter as completely as it was changed along in the forties when the filth theory of disease originated.

Q. I refer you to Mr. John D. Watson's report (of Birmingham, England) to the Metropolitan Sewerage Commission of New York dated January 31, 1913, wherein in discussing the various methods of sewage disposal for the city of New York, he says (page 30 of book entitled "Preliminary Reports on the Disposal of New York's Sewage, Number VII"): "What influences me most in favor of scheme 4, is the conviction that where it is possible to remove the bulk of the sewage of New York entirely away from its source to the ocean, it should be so removed, although the cost may be somewhat higher than it would be under a project like Scheme 3."

Will you state the various methods discussed by Mr. Watsón, and state how the above quotation is applicable to the conditions here at Chicago?

A. The Metropolitan Sewage Commission of New York was constituted a number of years ago for the purpose of studying the conditions and remedies therefor around New York Harbor and Bay; and it has projected four principal schemes or alternative methods for the treatment of the conditions at New York, which are discussed by Mr. John D. Watson, engineer for the Borough of Birmingham, England, and also by Doctor Fowler, who is in the same position in relation to Manchester, England, which are usually regarded as the highest development of artificial methods of treatment.

The 4th method, which is the one endorsed by both Mr. Watson and Mr. Fowler, is estimated to cost about $100,000,000 and is substantially a dilution method so far as the same can be applied to the New York conditions. It consists of interceptors for the purpose of gathering up the sewage; conduits for conducting the same to a common outlet, and pumping works. And an artificial island is to be created in the sea opposite Jamaica Bay and out beyond the entrance of New York Harbor; and the sewage conducted to this point and released on the outgoing tide, with only such treatment and screening as are necessary to operate the pumps and the system as a whole.

The alternative methods considered were three in number. One of them was known as land disposal, at an estimated cost of $180,000,000. Mr. Watson discusses this scheme as follows:

"Scheme 1.

Application of the Sewage to Land.

The popularity of irrigation as a means of purifying sewage is on the wane, chiefly owing to the extensive area required and the unsuitability of the land available.

The Berlin farm, which is the largest in Europe, continues to do good work. The largest farm in England was in Birmingham, but some years ago when land could no longer be obtained for less than three times its agricultural value, the au thorities abandoned irrigation in favor of the intensive method of purification on bacteria beds. The largest farm in France is at Paris, and there also the authorities contemplate a change of method whenever it is necessary to increase the purification plant.

Where all the conditions are favorable, irrigation is undoubtedly successful as a vehicle of purification, and one which generally yields consistently good effluents, but in New York the farm would be so collosal in extent that the conditions would not be invariably favorable. The available land is, I fear, limited to Long Island, the area required would exceed 150 square miles. It would necessarily vary in its adaptability for the purpose, and although the standard of purification need not be exceptionally high in view of the large volume of water into which it would ultimately be discharged, it would still be necessary to limit the volume of sewage to 10,000 or 12,000 gallons per acre, unless a great expenditure for under drainage were undertaken.

Sanitary Objections.—A great area of land lying between Amityville and Quogue overlies one of the sources of the city's present water supply, and its use for sewage purification would be a potential source of plague which no one would care to risk.

The mere saturation of 150 square miles of land with sewage would be a menace to the inhabitants obliged to reside in the District, and would be sure to produce mal-odors during certain states of the atmosphere, which would be highly objectionable, even if they did not markedly influence the health statistics of the District.

I disapprove of this method of purifying New York sewage on grounds quite apart from cost."

The second method discussed by Mr. Watson was oxidation by means of bacteria beds at a cost of One Hundred and Forty Millions of dollars. This is particularly significant in view of the fact that this method is now the leading alternative, and represents substantially the survival of the experimental methods of artificial treatment that have been more or less in practice and advocated for the last 40 years. It is described by Mr. Watson as follows:

"Scheme 2.

* * * * *

As the oyster beds will probably depreciate in value as the population of the District increases, it would not be wise on this account alone to incur the expense of this operation, more particularly as it is now admitted on all hands that the passage of sewage through a biological filter does not necessarily deprive it of pathogenic organisms, and in order to protect the oysters from the attack of a stray typhoid bacillus, it would in this case be necessary to sterilize before 1940 a quantity of sewage equal to about 700,000,000 gallons.

Danger of Nuisance.—Perhaps Barren Island is the very best site available for placing an installation of percolating filters, but it would appear as if Jamaica Bay were on the eve of great developments, and that Barren Island would not for long be the isolated place it now is. I regard it as of the utmost importance to establish sewage purification works where they are not likely to become a nuisance, and I have grave doubts about the wisdom of placing so vast an area as 1,000 acres of bacteria beds so near to an industrial center as they would be on Barren Island. In contemplating such a scheme there is a factor which should be taken into account, and that is the after effects of the evaporation of so much foul liquid as there must necessarily be from such an area of filters.

In 1911, when the summer weather in England was warmer than usual, there were complaints of smell nuisance at Henley, where the sewage is of about the same strength as the average American sewage, and where it is distributed over rectangular percolating beds by mechanical distributors moving backwards and forwards. Complaints were also made by residents near the Birmingham Works, where the sewage is sprayed over the beds by fixed nozzles.

The chief lesson to be learned from the 1911 experience is that an increase of flies is to be looked for in the neighborhood of bacteria beds in hot weather, and that objectionable smell adjacent to them is more pronounced during prolonged hot weather than at other times, e. g., seasons like the average English summer, when the temperature rarely exceeds 65 Fahr. in the shade. But a much more serious drawback to a great area of bacteria beds during spells of prolonged hot weather is the formation of vaporous 'clouds' due to the evaporation of sewage. These clouds appear to form over the beds in quiet weather. They rise to some distance above the earth, and at sundown, when the earth begins to cool, they return not alone as refreshing dew, but with offensive odor. If this occurred only in the vicinity of the bacteria beds, where the land is generally less valuable than at some distance, it would not be so serious in its consequences, but it generally occurs at some distance from the bacteria beds, the direction and distance depending upon the tendency and the velocity of the wind."

The third method consists of treatment at a number of convenient points so as to best accommodate the sewer system, without gathering the sewage at any one point, and local treatment works, to be precipitated or sedimented at such points by the tank methods coupled with sludge removal in tank steamers to the sea. This purification is partial only, and the question is raised by Mr. Watson as to whether it will not be a severe tax on the digestive power of the waters in the harbor as the city grows; and particularly so in the East River and in other sections where the waters are not sufficiently removed by the ebb and flow of the tides. Mr. Watson comments on this method as follows:

"Scheme 3.

Local Treatment Works and Outfalls.

It is probably not far from the truth to say that the only purification of organic matter known to nature is an oxidizing one, which is brought about indirectly by the agency of bacteria, but whether the vehicle by which the process is brought to fruition is the irrigation farm, the biological filter or dilution with large volume of clean water, the 'combustion' process is practically the same.

To protect the harbor from pollution, it is neither essential to confine the purifying process to one method, nor to one

locality, but whether it is expedient or wise to construct dozens of sewage purification plants in and around New York is an entirely different matter. Sewage from the various districts delineated on the plans could be sufficiently treated to admit of being discharged in the adjacent waters without creating a nuisance, but in some cases the treatment would have to be very circumscribed, and a greater burden would be placed upon the assimilating powers of the waters than they ought to be called upon to bear. * * *

Under this scheme there would be many outlets, all of which would require to be equipped with screens, grit chambers, tanks, and some kind of treatment works, before the effluent could be discharged and left for the nearest water to com plete its purification by assimilation."

These reports reduce the proposition to about this: That there are no alternatives even for the situation in New York that are not objectionable from one standpoint or another and that are not costly to operate and maintain; and even the dilution method as here proposed involves a considerable cost for maintenance and operation, as contrasted with the method of dilution as worked out here at Chicago.

And further that in all the alternative schemes, you may say, or two of the alternative schemes like land disposal and disposal on bacteria beds, the effluent must be sterilized before going into areas where shell fish and other products of the sea are grown and harvested.

This is also a most interesting proposition, because it brings together the latest consideration upon the whole subject matter by the most eminent authorities in this country and England, respecting the solution of the sanitary problem for our largest cities.

Q. You have made investigations to determine whether or not there are any currents here in the lake at Chicago, have you not?

A. Yes.

Q. What did you find from that examination or investigation which you made?

A. That there are no currents in the lake except those induced by the winds, and that they change with the changes in wind direction.

Q. From those observations, Mr. Cooley, with the Calumet River reversed as it will be when the Calumet Sag Channel is completed and in operation, and the Main Channel of the District and other works in operation, as is provided by the

statute of 1889, and the project as now operated, do you con sider that there will be any pollution of Chicago's water supply from cities like Waukegan or other cities near or around the city of Chicago?

A. No sir, not at any point within the central area or opposite the central area of Chicago. I cannot conceive of conditions which would bring currents of waters from that distance to opposite the mouth of the Chicago River, for instance. The probability would be so extremely remote as to be a vanishing quantity,—the possibility.

Q. How about the intake at the cribs, the water intakes for the City of Chicago?

A. Well, all our intakes are substantially this side of the Evanston line on the North and opposite 67th street on the South, and under the conditions that you speak of, there would be no sewage effluent going to the lake nearer than Michigan City or nearer than Waukegan. There is just the possibility that under contingencies that might occur in an occasional year we might get a little pollution from as far as Waukegan; but I assume that the conditions at Waukegan will be remedied as they already have the authority to organize a sanitary district on their own account at that point. Certainly with that done, I see no possibility of sewage pollution as affecting the water supply now taken at Chicago.

Q. Is there any pollution arising from lake vessels?

A. Yes, sir, especially these pleasure steamers going in and out morning and evening. I think that after the beams are all out of our eye, we are bound to go after the moats that come from that source, and there should be some regulation that will prohibit steamers from dumping their wastes into the lake within a reasonable distance of Chicago.

Q. Assuming that there was a regulation providing that the closets of lake vessels were closed and that they would not be allowed to deposit any wastes while passing from the Chicago River or from a position back of the break waters to points three or four miles beyond the intake cribs, what would be the effect if any of pollution from this source?

A. The chances of pollution would be greatly mitigated, as that distance in the lake would be more efficient in protection than 20 miles long shore. At the same time, I would like to see the limits extended further than that.

Q. The danger would not be material?

A. No, sir, it would be greatly mitigated.

Q. And there would be little danger from that source.

A. Yes. The fact of it is that normally all currents under all directions of wind resolve themselves into parallel currents along the shore and not usually setting in and out, in a direct line normal to the shore, so that distance in the lake means much more than distance along shore.

Q. What can you say as to the propriety of deriving an increment for the outlets of say Lakes Michigan, Huron, Erie and Ontario, from discharge measurements made at various times when the lake levels are shifting under conditions of unsteady flow, assuming that such measurements are plotted according to a simultaneous lake stage and discharge, and a line drawn through the center of gravity of the plottings.

Mr. Hopkins: Objected to on the ground that the witness has not shown qualification on this subject.

Mr. Adcock: Q. You may state in this connection Mr. Cooley, what studies and experience you have had, which would qualify you to answer this question?

A. My studies in relation to the subject matter go back to 1875 and '76 and 1881. And I was particularly charged with the investigation of the proposition in connection with the Drainage and Water Supply Commission in 1886-7, and at that time gave consideration to all the data that had been gathered by the Lake Survey and other agencies respecting the outflow of the lakes.

The results of these studies were printed in January, 1888, and later in connection with a series of papers before the Western Society of Engineers in 1888-9.

I also took up the matter in connection with the investigations of the International Waterways Commission, all the investigations of the United States section of the Commission being under my charge, and did at that time gather all the available material respecting lake fluctuations in the United States and Canada, and the same was published so far as relates to the stages of the lakes and certain fluctuations on Lake Erie, in the report of the Commission in 1896. I refer, in the matter that was gathered and printed in the report of the U. S. Deep Waterways Commission of 1896, to fluctuations in stage of water and not to oscillations or currents, except in relation to Lake Erie, in which case there was a special digest upon that subject.

In all these studies and investigations, it was recognized that the data was unsatisfactory, and in connection with all of it, it was recommended that there should be taken up by the United States a comprehensive series of measurements of

the outflow of the lakes over a wide range, so as to obtain a positive determination of the increment.

My conclusion from studies and investigations of this character, of the data when available, and from the special work which I had done in connection with oscillations of the lake, that it was not practicable to determine this increment by observations made through a limited range, owing to the effects of wind, of barometric change, of the oscillations known as seiches and other influences to which the lake surfaces and the connecting rivers with their very slender slopes are extremely sensitive.

In other words, we do not have in any of our outlets a condition of what may be called steady flow, and we could only determine the equivalent of a steady flow approximately by grouping a large number of observations within a limited range of a foot, and comparing it with some other group as far removed from that as possible.

The individual observation likens itself, to my mind, to the individual in a swarm of bees. Each bee is executing evolutions on its own account, and it would not be competent to determine the direction of movement of that swarm by drawing a line from one individual bee to another individual bee, or from one group of bees to another group of bees. They are going about each on its own account. But the line drawn from the center of gravity of this swarm of bees in one locality to the center of gravity when it has changed its place to another locality would be indicative of the bee line, and in my judgment there are no determinations of this character in which these individual movemnets within a limited range of fluctuation can be differentiated from the personal equation of the man making the investigation. Even over this wider range of 3 or 4 feet which ought to obtain in determining that increment, it will be subject to the infirmities due to the fact that you are dealing with a phasing mass of elements at each point.

That is the general idea that I have, and I have not thought it worth while to take up in detail the analytical studies of the observations that have been made over a limited range. But I think the official reports which I have examined in 1907 and 1910 verify my statement in the premises, as indicating that the subject matter is extremely illusive, and that they vary among themselves in their different determinations as much as 20 per cent., presumably made in the same office at Detroit.

Q. You are referring to what observations?

A. I refer particularly to the determinations printed by the International Commission in its report in 1907, and the increments published in the report on the investigation of the control of Lake Erie in 1910, and to the Lake Survey bulletins which are issued from year to year, each of which gives determinations and none of these determinations are in accord among themselves.

Q. You refer to the observations made by the Lake Survey made at different times on the St. Clair, Niagara, Detroit and St. Lawrence Rivers?

A. Yes, sir. All these observations are made under the supervision of the Lake Survey and have been worked up at its office, except those reported in 1900, by the Deep Water Board, which made observations on its own account in 1897 and 1898 until the Lake Survey mobilized upon the subject matter under the act of 1898, under the authorization for the re-survey of Northern and Northwestern lakes.

Q. You refer to 1897 and 1898?

A. Yes, sir, 1897 and '98, and in that analysis, in that tabulation submitted for the Niagara River in connection with the project of the Deep Water Board for the control of Lake Erie, they print 72 measurements which I have given some attention to. And in projecting their curve, they feel called upon to throw out arbitrarily 29 of these 72 measurements and treat the other 43 as true determinations.

I speak of that because I have had a very large experience on western rivers in analyzing that class of data, and it is purely an arbitrary proceeding, not justified in any investigation, and it illustrates in a way what I have attempted to say that by a system of elimination it is possible to find any conclusion, if you eliminate everything that does not agree with your preconceived ideas.

Q. The Deep Waterway Board to which you refer is the Board of Engineers on Deep Waterways, is that the title?

A. Yes, sir.

Q. They made a report in 1900?

A. Yes, sir, printed in 1901. It was constituted by an act passed in 1897, and was the successor to the International Waterways Commission, of which I was a member, and was called upon to carry out the recommendations of the Commission substantially in developing projects for ocean navigation into the lake by various routes, and to examine the question of control of Lake Erie and other lakes.

Mr. Hopkins: I want to preserve an objection by objecting to all of this line of testimony in regard to the increments of the various rivers which discharge the lakes. I move that it all be stricken out on the ground that it was understood, when the Government put in its rebuttal testimony and recalled the Lake Survey men, the experts who had done this particular work, it was the understanding that the defense proper would not put on any testimony in regard to increments.

Also I want to ask leave to reserve objections as to the question which was put in the hypothetical form, as to whether or not it included all of the elements that should be included in the question, that might be regarded as formal matters.

Mr. Adcock: There was no agreement as to that. Mr. Hopkins asked me as to what we expected to prove by Mr. Cooley, and I told him that we expected to go over various matters; and he asked about the hydraulic questions, and I told him that I expected that I might ask some questions about that, but would not go into it to any great extent.

Mr. Hopkins: That was not my understanding at all.

Mr. Austrian: You are holding Mr. Shenehon in reserve anyway.

Mr. Hopkins: I took the position then that I would not call those men until the defense was through, and I was certainly impressed with the understanding that nothing would be taken up afterwards that they would touch upon in their testimony.

Mr. Austrian: This is not any new matter.

Mr. Hopkins: It is nothing new but there might be something new—he has expressed opinions which these men might have answered.

Mr. Austrian: We haven't any objection to recalling them.

Mr. Hopkins: That is why I did not want to call them until you were through. That means calling them again.

Mr. Adcock: Some questions that have been taken up by Mr. Cooley here were considered by the witnesses who were placed on the stand last month at Detroit; all of it was gone into.

Mr. Austrian: If there is any question that you are taken by surprise, and you want to recall them, we haven't any objection. I understand your principal expert, Mr. Shenehon, when you put him on the stand, will answer all the witnesses we have to put on. Isn't that correct?

Mr. Hopkins: We are going to recall Mr. Shenohon, I presume.

Mr. Austrian: That has been the understanding right along, that Mr. Shenehon was to be the last witness. If there was any misunderstanding on the subject, we want to state for the benefit of the record that you can recall any witness that you want.

Mr. Hopkins: It means obtaining another authority to go up there again.

Mr. Adcock: Q. You are familiar with the depth of channels connecting the Great Lakes in 1900, which were used for navigation, were you not Mr. Cooley?

A. Yes, sir.

Q. In your opinion, would there be any injury to navigation by the lowering the levels of Lakes Michigan and Huron approximately 5 to 6 inches, Erie somewhat less, Ontario somewhat less than Erie, and the connecting channels an intermediate amount in proportion, and also assuming that the lowering of the water at the Poe Lock, would be somewhat less than the lowering of Lake Michigan?

A. I think there would be substantially no injury. The changes which have been made which influenced lake levels since the improvement of lake channels was undertaken, exceed in several instances all the changes produced or alleged to be produced by the diversion at Chicago, and such changes have not been considered worthy of attention, nor have they occasioned any protest or comment by lake carriers.

Again, the amount of change alleged is nominal in comparison with fluctuations that are going on by hour, by day, and through the months and the year. And vessel owners are obliged to load safe for the trip, and give a very much greater margin of clearance beneath the boat than is indicated by the alleged change.

Again, it is not competent to estimate the effects as a diminution in a fixed plane of reference, or as the difference between a fixed plane of reference and the bottom, as made in a canal or other absolutely still body of water; and the estimates that have been made up have been framed on that basis, and do not recognize these oscillations and changes in level which occur many times in the course of the trip.

Again, it is recognized as sound practice to provide a margin beneath the boat, not of inches, but of feet. As early as 1888 I made a study of that question and wrote a paper to the effect that the future Ship Canal should have a depth of not less than 25 per cent. of its draft beneath the keel. The International Congress on Navigation at Philadelphia year be-

fore last declared as one of the principles which govern restricted channels and canals, that it should have a depth of at least one meter beneath the keel, depending, of course, upon the character of channel and the speed which was to be considered. And the same proposition is worked out by Black, in his report on the Hudson River, very recently.

Q. That is Colonel Black?

A. Yes, sir.

Q. An engineer officer of the United States Army?

A. An engineer officer of the United States Army, where he lays down the proposition that the river should have a depth of two or three feet of clearance beneath the boat; that is, the improved channels should have a clearance of two or three feet beneath the boat; and gives some remarkable data in regard to the effect of the Hudson River boats attempting to navigate with the restricted limit beneath the boat.

And also for the further reason that any item of cargo that would fall off the boat, like a barrel of cement, would roll the skin and frame out of the bottom of the boat if it happened to strike it. There should be enough clearance there for safety. I know from my own experience in navigation on western rivers that a boat that would attempt to run within a foot or two of the bottom would be utterly uncontrollable in passing through the channelways of the lakes. So that a mere margin of a few inches would not be thought of by practical navigators; would not be accounted for and would not be known to exist, in the absence of a specific knowledge of a diversion of something of that kind existing at Chicago.

On the other hand, a lowering of the lakes by one foot, better by two feet, would be of profound advantage to every lake city about the Great Lakes, in giving a better freeboard for its sewer system and better elevation to its docks. All the cities about the lakes are built on low ground, margining some creek originally awash at high water of the lake, and the benefits of such a lowering to the sanitary welfare of the cities about the Great Lakes would be so great in proportion to the cost of producing two feet additional depth in all the harbors and channels of the lakes that it would be a vanishing quantity. And, furthermore, I conceive that if there were not diverse jurisdictions in the matter, but were one jurisdiction that looked at public welfare as a whole, a proposition of that kind would be a proposition to at once elicit legislative attention.

Q. You are familiar with the water power development of

the Sanitary District in the operation of the channel, as far as the flow of water is concerned?

A. I am.

Q. Is the amount of flow in any way affected by the water power development?

A. It is not, except in the distribution of the flow to a slight extent in the daily run.

Q. That is simply so far as the day is concerned?

A. Yes, sir.

Q. This development, or water power development, is merely incidental to the operation of the channel for sanitary purposes?

A. Entirely so. It has never, so far as I know, been regarded differently in any of the statutes, the constitutional amendment of the State of Illinois or any court decisions, or in the actual practice of the District itself.

Q. If it were not for this water power development there, that water would simply go to waste, would it not?

A. Absolutely.

Q. And the development is simply for the purpose of conserving that energy which otherwise would be lost?

A. Yes, sir. As I have already stated, it is a part of the theory of all of the projects and of the legislation relating thereto, that this was a proposition in conservation, although the name had not been invented at the time it was undertaken; and that all collateral utilities would be developed, including water power, waterways, dockage, reclamation of land and sanitary interests in the Illinois Valley as well as Chicago; and it was hoped that through the by-products thus created the burden on the taxpayer might be in some degree mitigated.

Adjourned subject to notice.

Depositions in the above entitled cause taken before the Commissioner, pursuant to notice, at the offices of the Sanitary District, Chicago, Thursday, March 12, 1914, at 11:00 A. M.

Present:

Mr. Albert L. Hopkins, on behalf of the Government.
Mr. Edmund D. Adcock, on behalf of the Sanitary District.

LYMAN E. COOLEY, recalled for further direct examination by Mr. Adcock, testified as follows:

Q. Mr. Cooley, what can you say as to the value of an increment which is determined from a set of measurements running over several days when the lake was at a uniform stage and another set of observations of discharge, a similar set of observations of discharge running over a period of several days when the lake was at a different stage, but uniform, as compared with the value of an increment derived from observations made at different times when the lake was changing, but covering a given range of stage?

A. That question, as I understand it, calls for a comparison between an increment under uniform conditions of stage, or steady flow, from observations or groups of observations taken at different horizons as contrasted with an increment determined from fluctuating stages, but covering the same range of horizon, without any general change in the levels of the lake itself. Answering it as I construe the question, I would say that there was no comparison to be made in the relative values of the increment determined under those conditions as defined. That, in the first case, you have a group of observations that determines approximately a condition of steady flow at one horizon, and also at a second horizon, between which points you can draw a line which will indicate approximately the increment, whereas, in the other case, you have fluctuating conditions or phasing conditions, from which you attempt to draw an increment which may be suggestive, but in no sense determinative.

I may liken it to my former comparison in regard to the swarm of bees. In the first place, the swarm of bees is at two different localities, and you can draw a bee line between them. In the second case your determination is based on the idiosyncrasy of individual bees who are taking long ex-

cursions in different directions without any change of the position of the swarm itself as a whole.

Q. What is the influence of ice in the several rivers, St. Clair, Niagara and St. Lawrence, upon the outflow and elevations of the Great Lakes?

A. The effect of ice is similar to that of a dam or constriction which decreases the discharge in the streams and impounds the water in the lake, and to that extent diminishes the flow through the intermediate channels. This may come from actual gorging of the ice, which has occurred in some years in the St. Clair River, where the flow is very radically interfered with, or it may come from a sheet of ice which converts the river into a tube, increasing in that respect the frictional resistence and diminishing the flow. These phenomena have been particularly studied in the St. Lawrence River below Montreal, occasioning there what is known as the winter flood, by raising the elevation of the river much above what it is ever raised by the ordinary flood in the river.

Q. What would be the relative effect of the retardation of flow upon the elevations of Lakes Michigan and Huron as compared with the retardation in the Niagara River as compared with the elevation of Erie, the retardation being in the St. Clair River?

A. The effect would be to impound the waters of Lake Michigan and Huron and diminish the amount of water passing through the St. Clair and Detroit Rivers and lower the stage relatively in Lake Erie. In other words, Lake Erie would drain out under those conditions.

Q. What would be the relative lowering of Lake Erie as compared with the raising of Lakes Michigan and Huron?

A. Every inch of raising that would thus be occasioned to Lakes Michigan-Huron would lower Lake Erie by 4.6 inches, in that ratio, in the ratio of the water surfaces, which is about in that ratio. In other words, it would be 4 to 5 times as great as the rise produced in Lake Michigan-Huron.

Q. Are there any ice effects in the Niagara River?

A. I don't know of any. I think usually it is a comparatively free discharge in the Niagara River except at the Falls and below, although there have been jams at Horseshoe Reef, but how far they have affected the results I do not know; but they have been temporary. I have not looked that matter up especially.

Q. What should be the relative magnitudes of the increments of the St. Clair, Niagara and St. Lawrence Rivers?

A. The magnitude of the increment should be inversely

as the relative fluctuations. In other words, the general fluctuation of Lakes Michigan-Huron, also of Lake Ontario, is considerably greater than that of Lake Erie, and the increment of the outlet by the Niagara River should, therefore, be greater.

Q. You refer to the annual fluctuations, do you not?

A. I refer to the general fluctuations.

Q. From year to year?

A. From year to year and through a series of years.

Q. Are you familiar with the physical conditions at the International Bridge at Buffalo?

A. Yes, sir; I have been there and have examined that situation; in fact, three or four times. I have also made a study of the Niagara River; that was when I was on the International Commission, with a view to seeing how far it could be made available in connection with a ship canal from Lake Erie to Lake Ontario.

Q. How would you regard the downstream side of this bridge as a gaging station in determining the discharge of the Niagara River?

A. It is the worst point that you could select, unless you selected the crest of the falls below.

Q. Why?

A. It is at the end of a rapid, where the motions of the water are extremely irregular; and is further complicated by the piers of the International Bridge, which are like so many rocks sticking up in the channel, and produce turbulent waters and disturbances of the current. In fact, in the vicinity of those piers, a man could not be sure in what direction a meter was pointing. It might be standing on its head part of the time.

Q. What is your opinion of the correctness of the Niagara River discharges as shown by the Engineer's reports, Government reports?

A. As a general proposition I think they are—though they appears to be in some degreee consistent among themselves —as a whole they are all too low. They do not give the discharge of Lake Erie properly. I am led to that conclusion by the very small difference in the discharges as given for the St. Clair and also the Detroit River, as compared to the discharge in the Niagara River, and the very great increase in discharge over the Niagara River as given for the St. Lawrence at the Galops Rapids, as the increment of an additional basin in each case is about the same.

In other words, the Lake Erie basin adds about the same

additional area for drainage that the Lake Ontario basin does and the Erie Basin; and the results are not in accord with what they should be.

Furthermore the Erie basin is usually considered to be a little further south and to have a somewhat further consumption of water in vegetation and evaporation from the surface of the lake.

On the other hand, the rainfall on the Erie basin is given as 36 inches as against 33 for the Ontario basin, which compensates in some degree. Making every assumption either way that can be made, the discrepancy is larger than it should be.

Q. Where do you obtain your figures as to 36 inches on the Erie basin and 33 on the Ontario basin?

A. Those figures are from the U. S. Weather Bureau, a special compilation made a number of years ago (1899) and published from year to year in the bulletins of the U. S. Lake Survey.

Q. What effect would the dredging and dumping of dredge material in the shallows at the mouth of the Detroit River be likely to have on the discharge of that river?

A. It depends altogether as to where and how that material is placed. If the material from these deeper channels is placed in the shoal waters, and in such manner as to give a more regular channel than formerly existed, the effect would be to increase the discharge rather than diminish it, or compensate it.

In fact you might conceive a channel to be deepened and the material placed in such a way in the shoaler parts of the channel as to double its mean depth, and under those circumstances it would increase the discharge from 40 to 70 per cent. It is all a question of how the material is disposed with respect to that.

Q. What would be the effect of dredging, independent of the filling?

A. The effect of that would be to increase the hydraulic capacity of the stream, make a larger discharging capacity for a given stage.

Q. What has been the change in the outflow capacity in the St. Lawrence River?

A. There have been two or three,—three changes that have been made by works, two of which were under the Canadian Government. In 1881, the Galops Channel was deepened from 10 to 16 feet, for the purpose of enabling down-

stream navigation without passing through the canal; and the estimated change in the level of the river at Ogdensburg from that, was to lower it about 1 foot. The facts in regard to that are reported in the report of the Chief of Engineers for 1882.

A further change was made by closing the Gut Channel in 1903, and the effect of that was estimated locally at about half a foot, and Lake Ontario very nearly the same amount, about a third of a foot. This closing had the effect of raising the level of Lake Ontario. This was also done by the Canadian Government.

Then there has been another effect on the St. Lawrence produced by the opening of the Massena Canal between Farren's Point and Cornwall, by which the waters are diverted from the St. Lawrence over to Grass River to produce water power. This canal has a capacity of 25,000 second feet, and by the increment of the International Waterways Commission on that part of the river, this canal produces an effect of about 1.4 feet lowering the water surface in that reach.

Q. With reference to the Niagara River, what change has been made in the outflow capacity?

A. Along sometime prior to 1890,—I don't recall the date —the Horseshoe Reef was cut down, and certain improvements made in the Rapids by cleaning up the channel so as to take 18 feet. Formerly 17 feet had existed, in a sinuous channel. There were also quite extensive works down at Strawberry Island, down opposite the head of Grand Island, so as to extend this navigation of 18 feet down to Tonawanda. There has been some work done between that point and Slosser in cleaning up the bottom of the channel, and in some excavation, so that a navigation of 16 feet could be carried down to Slosser, immediately above Niagara Falls on the American side.

Q. What effect would that be likely to have on Lake Erie levels?

A. The effect is to make a better discharging channel of the Niagara River, and to lower the levels.

Q. Take the St. Clair and Detroit Rivers, what have been the changes in the outflow capacity?

A. The original depth at the Lime Kiln Crossing at the mouth of the Detroit River was about 11½ feet below the present improvement plan. This has been deepened to 21 feet in the Amherstburg Channel, and 22 feet in the Livingstone Channel, both of which are broad. I think the Am-

herstburg Channel is 600 feet wide and the Livingstone Channel 450 feet part of the way. There has also been dredging at Grosse Point and for some distance out into Lake St. Clair in order to improve the entrance to the Detroit River from Lake St. Clair.

There have also been improvements at the Ship Canal's south pass of Lake St. Clair (originally 8 feet, increased to 18.3 feet); and in the approach to the St. Clair River on the bars above Ft. Gratiot, the channel has been deepened 2,400 feet wide through these bars, to a depth of 21 feet below the old plane of reference. (18.9 on new plane.)

The effect of all these improvements has been to readjust the slopes in the St. Clair and Detroit Rivers; also the level of Lake Michigan and Huron and Lake St. Clair, with respect to Lake Erie.

There was also a change in the level of Lake Huron-Michigan, which has been attirbuted to these works occurring in 1886 to 1890, through the cutting out of the gorge at Port Huron, where formerly a rapid of 16 inches existed. The effect of this has been estimated at about .9 of a foot. Including these other changes, the Board of Engineers on Deep Waterways, report of 1900, estimated a change of about .9 between Lake Erie and Lake Michigan. The Lake Survey Report of 1911, reports a further change of about 3 per cent. in the capacity of the Port Huron outlet, an increase by 3 per cent., which would produce a change in level of 3 to 4 inches (3.3 inches) additional, according to their own increment—or the last increment of the Lake Survey, rather.

Q. What is your opinion as to whether or not the discharge due to a change of lake surface coincides in time with the crest of the wave set up by the change?

A. It does not. Any immediate change in lake surface would propagate a carrier wave from the outlets, that would travel very rapidly, like a tidal wave; whereas, the time required for the outlet itself to adjust its regimen or become entrain, as they say, would be a considerable period of time, many times longer than the time of propagation of the carrier wave. For instance, a carrier wave at depth of 25 to 30 feet, the water would travel from 19 to 21 miles an hour. Whereas, to establish a condition of steady flow in the river like the Niagara River, it would take from 12 to 24 hours, probably.

Q. What investigations or studies have you made to determine this question?

A. You might say I have been determining the matter for 40 years. I have given a good deal of study to movements in water in canals and to the movement of carrier waves as affecting navigation; and tidal movements which are of the same general character, where an impulse is transmitted through a stream or body of water without in itself transferring any considerable body of water. And where these impulses do exist, they produce local stages of water or oscillations, and they greatly complicate any relations of stage to flow.

For instance, a tidal wave will start from New York Bay up the Hudson River; produce a tide all the way to Troy, 150 miles, raising the water there a foot, and at Albany, 7 or 8 miles below, about 2 feet and ½, in the low water season. By the time that wave reaches Albany, the level at Poughkeepsie is at low water. You produce a high tide stage at Albany, with no flow and the steepest slopes below. It utterly destroys all the relations which are assumed to exist under conditions of steady flow. And observations made under the conditions of undulations in the lake are subjeet more or less to that class of influences producing false stages with respect to the measurements.

Q. You spoke of "phasing conditions." Would you describe a little more fully what you mean by that, with reference say to Lake Erie and the discharge of the Niagara River?

A. I refer to a phase as something that is produced by changes in level under conditions of unsteady flow. For instance, a river is rising and it produces a discharge curve which is quite separate and distinct from the discharge curve produced on the falling stage; and that is spoken of as the phase of the rising and falling stage.

A high barometer passing over Lake Michigan to-day will lower the lake by several inches and transfer that water to Lake Huron, and it may pass over Lake Huron to-morrow and transfer that water to Lake Michigan. And there will be a fluctuation at Port Huron, first upward and later downward. The whole level of Lake Huron, in fact, has been changed by perhaps a foot throughout the complete range. This occurs from barometric effects. You would get a phasing flow down the St. Clair River; in other words, not a condition of steady flow. Conditions of slope and head and reservoir capacity of the channel, as indicated a change which is not a steady flow. The same effect occurs from these phe-

nomena called seiches. Those are never quite absent, and sometimes reach amplitudes running up into feet, two or three feet. In fact higher undulations have been observed. Those are quick fluctuations that send pulses down the river and prduce temporary phases.

Then, again, the wind may lower or raise the level of Lake Erie at its mouth and produce a phase there that would take several days for it to readjust itself, provided the lake continued long enough for it to readjust itself between Lake Erie and Lake Huron. That would affect the flow. In other words you would get a condition differing from steady flow. Any condition that is not a condition of steady flow, and due to temporary causes of this character produced phases just as tidal waves do, by which they destroy the true relations between stage and volume.

Q. Volume of discharge?

A. Yes.

Q. Have you made any observations upon Lake Michigan which indicated any such conditions as you have described? If so, will you state what investigations you have made?

A. In 1886 and '87, I undertook a very comprehensive series of observations directed particularly toward lake currents, and the effect of fluctuations for the Drainage and Water Supply Commission, having relation primarily to the water supply at Chicago. I believe this is the most comprehensive set of observations ever made respecting lake currents and seiches. Our automatic gages recorded for two years the oscillations of the lake surface, and from the record of these gages the seiches running at 20 minute intervals are characteristic, usually running one to two-tenths, and quite frequently reaching a larger amplitudes, and on that record they ran up over 18 inches, and kept up for two or three days.

I also had gage observations made at five minute intervals on seven gages around Lake Michigan; and on one day found that every gage on Lake Michigan lowered by about five inches, as I recall the figures. In other words, five inches of water disappeared from Lake Michigan in one interval of 24 hours. I made investigations at that time to see whether it was feasible to transfer that water to Lake Huron through the Straits of Mackinaw, and found that it could have readily passed that way. The observed currents that take place at Mackinaw indicate the feasibility of such a transfer of water. It does actually take place.

Q. Do you remember where those gages were located?

A. One was located at Ludington, one at Manitowoc, one at Grand Haven, Milwaukee, St. Joseph, Michigan City and Chicago. I will add in that connection that I made very extensive series of current measurements in Lake Michigan by large floats and log lines, and some of those measurements were taken in 250 feet of water.

Q. Will you describe the method of making those measurements?

A. The bottom float so-called was made of galvanized iron 30 inches high and about the diameter of a flour barrel, and was connected to a small can as a surface float, which had just sufficient displacement to carry the lower float. When a surface current observation was sought, these floats were put inside of each other as it were and the cord connecting them was lengthened out so as to give the current at any depth up to 250 feet, which we did actually observe.

The measurements were made in the open lake from an anchored boat held in position by two anchors; directions taken by compass bearing; the distances measured on the log line and marked with red paint at intervals of ten feet, the log line consisting of the strongest procurable seine twine. These floats were started from the side of the boat and played out until they acquired steady velocity and the marking on the same twine was noted and the stop watch started. They were run then 100 or 200 yards further, and the time taken by stopping the stop watch. The strain on the twine was very heavy when pulling in the floats, but after the float was started back, the lower float came edgewise to the water and came back very easy, so we could pull it back with our log line.

Q. You are familiar with all parts of the main channel and the Chicago River, as you have stated?

A. Yes, sir.

Q. Assuming that you had a uniform flow of say 4,167 cubic feet of water per second through the channel, the Chicago River and the Main Channel of the District down to the power house at or near Joliet; and that you changed the dam, the openings at the power house, so that you immediately had a flow at that point of 10,000 cubic feet of water per second, how long would it take to establish a uniform flow of 10,000 cubic feet per second through the entire length of the Drainage Channel and the Chicago River to the Lake?

A. Speaking offhand, the least time, or the lower limit,

I estimate would be the time required for 10,000 feet of water to displace all the water in the channel, which would be something like half a day, and the other limit would be double that, which expresses the rule in regard to uniform acceleration. I should say somewhere between 12 and 24 hours from Robey street to Lockport. But I would not undertake to state that definitely unless the stream was running at the hydraulic capacity of the channel parallel to the bottom. The idea is this, that you cannot establish a regimen until you have at least displaced all the water in the river between the points considered or the points that are affected in the results; and then some to allow for the fact that the change is progressive.

Adjourned subject to notice.

Deposition in the above entitled cause taken before the Commissioner on the 23rd day of April, 1914, at 2:00 P. M. at the offices of The Sanitary District of Chicago.

Appearances:

Mr. Albert L. Hopkins,
On behalf of the Government.
Mr. Edmund D. Adcock,
On behalf of the Sanitary District.

LYMAN E. COOLEY resumed the stand and testified further as follows:

Cross-Examination by Mr. Hopkins.

Q. Mr. Cooley, you were rather opposed to what is known as the Calumet Project. weren't you?

A. I have been opposed to some phases of the Calumet Project.

Q. Just what phases?

A I was opposed to making a channel in the Calumet District which was unduly out of proportion to the main channel. There was proposed at one time a channel of 4,000 seconds feet in that region, and at another time a channel of about 1/3 of the capacity of the Main Channel. I regarded those as out of proportion to the population to be benefited, and opposed the construction of channels of those dimensions.

Q. What is the size of the channel now being constructed?

A. The channel now being constructed has a capacity of about 2,000 seconds feet, or about 14 per cent. of that of the Main Channel; whereas the original project of 1887, and the project of the Pure Water Commission in 1897, the Expert Commission in 1901, suggested about a thousand feet, or about 10 per cent. of the original projected capacity of the Sanitary Canal.

Q. In other words you do not believe in that Calumet plan to make it a ship canal for deep draft vessels?

A. No, sir, the navigation feature is in a way incidental, and whatever navigation advantages there may be out of a channel properly proportioned to meet the relative population which may exist in that region, why of course I am in favor of that incidental use, but not of constructing a channel *per se,* at a cost to the tax payers, for that especial purpose of navigation.

Q. You made a statement in January, 1905, didn't you, that "Chicago would be robbed of its commerce and compelled to pay 95 per cent. of the cost of being robbed"?

A. I did make such a statement.

Q. What was that in reference to, Mr. Cooley?

A. That was in reference to the project then under consideration, and advocated by the then Board of Trustees, to produce a channel in the Calumet region about 1/3 of the capacity of the Main Channel, which I considered as entirely subordinating the Main Channel and the interests of the great population at Chicago to what might be called the "appendix" of the district.

Q. What would have been the cost, what was the estimated cost of the channel as then contemplated?

A. I do not recall that; but I think about eighteen to twenty millions.

Q. What is the estimated cost of the present works?

A. About 6,000,000. The 6,000,000 that I have in mind is for the channel proper itself from the Main Channel to the connection with the Calumet River. The other elements of the problem have been estimated, but whether the intercepting sewer system that has been suggested in that connection is to be undertaken by the District or the City of Chicago is perhaps open to discussion.

Q. Wasn't the amount estimated that that canal would cost at that time about $12,000,000?

A. I don't recall the figures definitely.

Q. To refresh your recollection, wasn't this statement made by you: "Calumet would have to pay about 5 per cent. of the cost of the new Ship Canal, and the people of Chicago would have to stand the balance. In other words, Calumet would have to pay about $600,000 for a canal that will benefit a few local interests, while Chicago must spend $11,400,000 for the enterprise. The deep ship canal, I understand, would cost, as now figured, at least $12,000,000, and it would be built on the theory of draining the Calumet region." Didn't you make that statement?

Mr. Adcock: I object to that, unless there is a statement of the place and time, etc., included, wherein such statement might have been made.

Mr. Hopkins: At or about January, 1905.

Mr. Adcock: And subject to the further objection that there is no statement or specification as to how the statement was made, whether it was in conversation with someone, or whether it was a statement to a newspaper reporter, or what not.

Mr. Hopkins: Q Do you recall, did you make such a statement to anyone, Mr. Cooley?

A. I will not say in regard to the whole statement. The part that you first cited has been much quoted, and I remember that distinctly, but the estimates I do not recall; the estimates that you just now read, that part of it.

Q. Assuming the estimates in there are correct, the figures, that was the truth of the matter, wasn't it?

A. Yes, sir, those estimates were probably estimates that were given out by the District at that time. I had made estimates of my own, and my recollection in regard to those estimates is what I first testified to.

Q. You also made a statement that was printed in the Record-Herald of October 1, 1907, in regard to this matter, as follows: "It is not a question of the immediate expenditure of large sums of money, as would be required for a lake front harbor, or in the attempt to shift our commerce and population to the Calumet region, where less than 4 per cent. of our wealth is now located, if the assessor is the judge; but rather the expenditure of the normal tax levy in harmony with a defined policy and plan. Harbor developments that do not serve existing population are speculative and a fraud on the people who are compelled to pay for them. People are deceived by sophistry and by reasons invented

to justify the diversion of public funds." Didn't you make that statement, Mr. Cooley?

A. I think the statement is correctly quoted.

Q. In the same article you also said, didn't you: "Let us complete the Main Channel between Robey Street and Summit for a width of 300 feet, for which right of way and bridges have been provided." And then later: "A handful of population in the Calumet can be otherwise cared for at a moderate fraction of the cost, and the State of Indiana can be compelled to care for its own under the doctrine of law handed down in the St. Louis case." You made those statements, too, didn't you Mr. Cooley?

A. Yes, sir. I would like to make a remark in connection with those, when you are through making the citations.

Q. Go ahead?

A. The citations last made are from an article entitled The Harbor Problem of Chicago, which was intended to show that the proper development should be an evolution from the Sanitary Canal in and behind the city, and not on the Lake front, and not in the Calumet region. There has been a strong feeling in many quarters that the future harbor of Chicago should be in the Calumet, which I do not believe in and have so stated on many occasions. Nevertheless there is a population there now amounting to about 134,000 by the last census and about 63,000 more in the State of Indiana east of the State line and practically included in the Calumet region considered as a whole, which does have sanitary problems and which must be taken care of from the sanitary standpoint, entirely independent of any commercial development; and which, from the beginning of the consideration of this matter in 1887, has been considered worthy of a branch channel varying from 10 per cent. up of the capacity of the Main Channel.

Q. Have you yourself made any estimates as to other methods of sewage disposal in that region than by a channel, and dilution?

A. I did at one time entertain very strongly the idea that it was feasible to provide for that region by treatment on land; it being in effect the only part of the Sanitary District as now situated which had land which could be availed of for such a purpose. But the anticipations which I have entertained at times respecting the availability of such methods have grown less and less in my mind as experience has

not borne out the hopes which were entertained respecting such methods.

Q. Do you recall writing a letter about April 23rd, 1907, to Mr. E. A. Halsey, Chairman of Committee on Sanitary District Real Estate Board, Chicago, Illinois?

A. I do not recall it.

Q. To refresh your recollection, the letter is as follows:

"Dear Sir:

In respect to our conversation, I note as follows:

The Sanitary District bill at Springfield provided for 1 per cent. taxation without limit as to time, and for the full constitutional indebtedness of five per cent.

The original law of 1889 gave a tax limit of 1/2 of 1 per cent. and a bond limit of fifteen millions; and this has been sufficient for all purposes of the Sanitary District up to this time, except that the tax limit has been temporarily increased for special purposes for two or three times, and the bond limit increased on account of the Chicago River improvement, to a limit of twenty million.

It is a very sad comment that there should be occasion at this late day for any increase in bonds, or of taxation, for more than a temporary period of three to five years, for some such purpose as provides for the full volume of water at an early day, or completing the Main Channel for waterway purposes in co-operation with the United States.

It is understood that this unlimited increase of taxation and bonds is to be devoted to the suburbs which were annexed in 1903. The sum estimated as required for the suburbs ranges from sixteen to eighteen million dollars. These suburbs have paid into the tax account from $600,000 to $700,000, and their assessed valuation is but six per cent. of that for the entire Sanitary District, so that their contribution to the works which are projected for their benefit will not much exceed one million dollars, and Chicago proper must foot the balance of the bill. There is absolutely no occasion for this, as all works required for the suburbs can be produced for 30 to 40 per cent. of the estimate, and such works can be deferred until the Main Channel has been completed and the water introduced therein as contemplated by law.

But this is not the worst of it. The proposed solution

for the Calumet region gives to that section forty per cent. of the water supply allowed for the Chicago River basin. The assessed valuation of this region is only 3.71 per cent. of that of the Sanitary District, and the ratio has not changed since 1888, when the Sanitary District law was drawn. In other words, the statements that the Calumet region is growing faster than the balance of our city, and that it needs extraordinary provision out of proportion to its relative population and wealth, is absolutely false. At the present rate of growth, the Chicago River basin will exhaust the full capacity of the Main Channel before it can be completed and the bonds paid. There is the highest expert authority for a much cheaper solution of the Calumet problem, which will not be complicated with the State of Indiana, and which will not interfere with the uses of the Main Channel for the Chicago River basin. In view of this, it is entirely inexpedient for the Sanitary District to take a position hostile to the conclusions of the authorities of the United States, if this city and this state is to realize a deep waterway in the early future.

I can see absolutely no argument for the Calumet proposition as it is now being urged, and I cannot understand why the taxpayers of this city are not more alive to their self interest, nor can I understand further what motives are influencing the Drainage Board to such a gross misapplication of the public funds.

Yours truly,

LYMAN E. COOLEY."

Did you write such a letter as that to Mr. Halsey?

A. What date is that?

Q. April 23rd, 1907.

A. I think I did.

Q. When you speak of "There is the highest expert authority for a much cheaper solution of the Calumet problem, which will not be complicated with the State of Indiana, and which will not interfere with the uses of the Main Channel for the Chicago River basin," what method did you have in mind at that time?

A. I referred to the report of Messrs. Hering and Fuller.

Q. 1906, was it?

A. Yes, sir, in connection with the estimate and report to the International Commission or the American Section thereof, in regard to the Calumet region. They at that time

had developed a very attractive proposition by means of sprinkling filters for the treatment of the Calumet region, which could be applied progressively with the growth of population; and which involved at the outset only a fraction of the expenditure, capital expenditure, required to develop the alternative method by means of a channel through the Sag. And in view of what seemed to me to be a prior claim or necessity, which was the completion of the Main Channel, it seemed to me that the District at that time, as I expressed it very forcibly, should curtail its suburban enterprises and devote its resources to the Main Channel, and adopt expedients of that character for which there was, as I said, the highest expert authority. But the District did not take that course. Neither did they carry out the project for the enormous channel which was then proposed for that region; but the project at that time was academic; it has not proven up by experience, and so as I have already indicated, at that time I entertained very great hopes that these artificial methods would involve, and thought perhaps they did in view of the sanguine nature of the report, a competent solution, I am not now so persuaded that that opinion was justified.

Q. You are in favor of an inner harbor?

A. Yes, sir.

Q. And in order to get at that properly for big shipping, and a great amount of it, the river would have to be greatly improved, even as it now stands, wouldn't it, Mr. Cooley?

A. Yes, sir, either that or the alternative cut made across the South Side, or direct access. In fact the project of 1901, of the Expert Committee, of which I was the working member, did develop a project for a river 300 and 360 feet wide in its different parts, and 26 to 30 feet in depth in its different parts, which project was competent to take care of all the water which the Sanitary Canal was designed to carry and capable of carrying. But that project was not actually adopted, like other of my projects have failed of adoption.

Q. Of course you could not have any more water through the Chicago River as it now stands without increasing the current, could you?

A. The current in the Chicago River as we now have it is conditioned by the unimproved sections thereof, between Harrison and Madison Streets.

Q. My question is: As it now stands, any additional water means more current?

A. At those localities, yes, sir.

Q. Not necessarily at those localities, wouldn't it be any place, the more water you have through there now the more current you have?

A. Yes, it would be of greater velocity throughout.

Q. And at least to that extent it would change the condition of the Chicago River?

A. Yes, sir.

Q. Did I understand you to say on your direct testimony that you have made studies and investigations of various European methods of disposing of this sewage?

A. When you speak of European methods, I presume you mean the alternative methods?

Q. Yes, aside from the dilution method?

A. I have made general studies respecting that.

Q. What study did you make? Did you study reports or what?

A. I was a member of the original investigating machinery upon the subject matter for the city of Chicago, and for the State Board of Health in this state, and reviewed in that connection all of the information available respecting alternative methods, and have kept informed respecting their development since.

Q. In what way have you kept informed?

A. By reading reports and studies upon the subject matter.

Q. As a matter of fact sometime ago there was more or less of an extensive inquiry made of various American Consuls and representatives, in regard to European methods, wasn't there, either by you or by the Sanitary District?

A. I am the Chairman of a commission of the Sanitary District that has had under advisement for the past year and a half the whole subject matter of alternative methods. And that commission has been engaged in making inquiries respecting the practice abroad and in this country, with a view of making a full and complete special exhibit of the practice of the world respecting sewage disposal. That investigation is in progress.

We are also charged, not only with that general inquiry, but with every aspect of the question, and with an inquiry respecting filth producing industries in this city.

Q. Just what information, say, did you get from Paris, for instance? What I am trying to find out is whether someone went over and visited it personally or whether it is from

reports of the authorities in charge, or just what is the nature of the information?

A. Our inquiries have been through the Consular Agents of the United States, who have undertaken to answer or submit to the authorities a series of questions, and to gather up reports which would cover the questions that have been propounded.

Q. Wasn't the report in regard to the Paris condition that it was a good one and satisfactory?

A. I don't recall now. These reports are very voluminous. I had a couple of assistants working on them for a number of months in order to make a digest and get them in shape. I do not recall at this moment any particular point respecting Paris, except that the system of artificial disposal was not to be extended in Paris.

Q. Wasn't that due to the difficulty of securing land?

A. In part to that. That was given as one of the reasons. The sewage of Paris has never been fully disposed of on land. It has been disposed of to market gardners who take it as they find occasion to use it in their cropping, and the remainder has gone to the river.

Q. Now about Berlin, was the report there that the conditions were satisfactory or unsatisfactory? I mean with the artificial treatment?

A. The treatment at Berlin is a land treatment, and on the whole has proven satisfactory; perhaps more satisfactory than any metropolitan city in the world. But that is due to conditions which lend themselves peculiarly to the methods there adopted, and which forbid other methods.

For instance, the rainfall at Berlin is only about 24 inches, and an irrigation proposition in that region is good in itself. Berlin is surrounded by a large quantity of sand barrens which are infertile and which are peculiarly adapted to treatment of sewage. Its proper drainage is the River Spree, which is scarcely larger than the Des Plaines River and at times is substantially dry. And the putting of sewage into such a stream without dilution is intolerable, so every condition at Berlin demands some other treatment than by dilution, and all the conditions are more favorable to a land treatment than anywhere that I know of except Denver, where I had occasion to suggest a similar method, when I was consulting engineer of the Union Water Supply Company for the city of Denver some years ago.

Mr. Adcock: Q. How about the consumption of water per capita there, as compared with Chicago?

A. I do not recall the actual consumption at Berlin, but usually in those cities it runs from 40 to 60 gallons or about 1/4 what it is in Chicago; so that the volume of effluent required to be handled is relatively small.

Q. How about the climatic conditions there compared to Chicago, as related to sewage farming?

A. Much more favorable. Their rainfall is about two-thirds of that at Chicago and their summer temperatures are moderate and as I have already remarked, the soil conditions are good and proper.

Q. It does not get as cold there in winter either?

A. No, sir.

Mr. Hopkins: Q. It gets as cold in Denver, doesn't it, Mr. Cooley?

A. Yes, sir, but Denver is a place that I have been looking up. As I have already stated, I was consulting engineer of the Union Water Company there for about five years; a town of 80,000 inhabitants; it turns its sewage into the Platte River, the South Platte, which is entirely devoid of water at certain seasons; has a wide sand bed with a grade of about 7 feet to the mile. And with only the sewage of Denver going in there, without any dilution at all, there is no nuisance, and the sewage effects dissappear in about 12 or 14 miles. It is a remarkable case, which I am going to give further study to.

Q. Mr. Cooley, were there any cases reported where some treatment was made, some artificial treatment made of the sewage, and then the effluent deposited in the streams?

A. Yes, sir.

Q. Small or otherwise?

A. Yes, sir. The statements in regard to the Birmingham District, and in regard to the Manchester District are quite full in that matter. In the Manchester District there are four or five treatment works, in which all the sewage and commercial wastes and the large manufacturing wastes of the Manchester District are handled, and the purification is, perhaps, carried on to a greater extent than any other foreign city, and perhaps any city in the world, by reason of the fact that the effluent waters feed the Manchester Ship Canal; and they even go so far in the Manchester District as to treat the storm waters which run off the lands, and which are highly polluted, before they are allowed to go into the canal.

Q. Is that Ship Canal a sea level canal?

A. No, sir. It is a lock canal, and it is fed from these land waters, and in seasons when they are insufficient the water is re-pumped at the locks from the lower level to the higher level, in order to make the lockage.

Mr. Adcock: Q. To maintain the depths?

A. Yes, maintain the levels and the water for the lockage. I went over this Manchester Ship Canal in 1909, after all this treatment process, and I rode down to the Sea in a sludge boat from Salford; and the waters in the Manchester Ship Canal are worse than I have ever seen them in the Chicago Drainage Canal, after all this treatment.

Mr. Hopkins: Q. What is the average flow in cubic feet per second in that ship canal?

A. I would not undertake to say. I have no specific data respecting that at this moment in my mind.

Mr. Adcock: Q. There is nothing but the effluent coming into the canal?

A. There is at Manchester the river Irwell, and it has a drainage basin which contains the city of Manchester and a number of other Boroughs, and the River Irwell normally is not a large stream, nor does it drain a large water shed, but exactly how much I do not know.

Q. It is only the effluent that goes into the Ship Canal, is it not, from Manchester?

A. The effluent from Manchester and its suburbs.

Q. The effiuent from sewage disposal works?

A. Yes, sir.

Q. That is the sewage that is discharged there has all been treated?

A. The sewage in that district before being allowed to enter the canal is treated. And the conditions are as I have stated.

Mr. Hopkins: Q. Mr. Cooley, isn't it your opinion, that if the sewage of Chicago were screened and settled by some artificial method, as for instance Imhoff tanks, that 4167 cubic feet a second would then take care of a much greater population, that is assuming that the 4167 feet is only to take away the effluent, after the screening and settling of the sewage?

A. No, sir. It would perhaps increase to a limited extent the number of people which could be served by a given volume of water. But these methods do not undertake to handle more than the coarser impurities, and take out a lot of inert matter. The real putrescible matter removed is perhaps 20

to 30 per cent., and that largely carbonaceous so that it seems to me that the advantage that you gain by that, the saving that you gained by applying such methods, involves a cost far out of proportion to any other element in the problem.

The theory has generally prevailed that such a method of sedimentation represented by the Imhoff tank stableized the effluents and made them less susceptible to rapid decomposition; and that by reason of that the dilution water would be more effective; but I think that that is a hope,—has been a hope rather than a reality.

I can see no reason in the rationale of sewage treatment why that should be so; and I am unable to find any experience that actually justifies such an anticipation.

The largest treatment works that we have had in this country, at Columbus and at Atlanta, in the past year seemed to show that the effluents have not in reality been stableized, although a part of the putrescible matter has been removed.

Q. Every winter, there is more or less a raising of Lakes Michigan-Huron due to ice conditions in the St. Clair River, is there not?

A. I should say as a general proposition that Lake Michigan-Huron reached their lowest stage usually in March. There are winters in which—

Q. Lowest or highest?

A. Lowest stages in March.

Q. Michigan-Huron?

A. Yes. There are conditions in the St. Clair River where the outflow is retarded, but at all times during the winter months it is still greater than the inflow, so that the most you can say respecting that is owing to ice, the lakes do not fall as rapidly nor get as low as they would in the absence of ice in the outlets. There have been cases of absolute gorging for several weeks.

Q. Such ice conditions would vitiate the exactness of any percentage fluctuations between the two lakes, which percentage fluctuations were based upon open season flow, wouldn't it?

A. It is an element that ought to be taken into account in determining ratios of fluctuations. How much it would modify or change those ratios, I am unable to say without making a critical examination. I think however, that the general historic relation that has existed ever since 1819 in regard to the fluctuations of the several lakes would not be

greatly changed, but would rather be increased than diminished, that is the discrepancies would be increased rather than diminished if the outlets were perfectly free and open throughout the year. In other words Lakes Michigan and Huron would fluctuate through a wider range than it actually does, in comparison with Lake Erie.

Q. I was speaking of the ratio of fluctuation between the two, whether it would be the same?

A. I understood the question to refer to the ratio in the complete range of fluctuation.

Q. No, one lake to the other, as to whether there would be a uniform fluctuation between the two, ratio of fluctuation between the two lakes?

A. Well, in answer to that view of the question, which I did not get, the retardation of the flow between Lake Erie and Lake Michigan-Huron, would have the effect of diminishing the stage of Lake Erie with respect to Lake Huron-Michigan, or vice versa.

Q. In other words the point I am trying to make is that the ice conditions interferes with the ratio of fluctuation between the two lakes, which ratio has been determined under open season conditions?

A. Yes, sir undoubtedly does.

Q. You spoke of certain observations made in the Hudson River in regard to tides, and that you did not think that the water traveled with the wave. How do you account for the difference in elevation, unless there is more water at a particular point?

A. The water is actually moved through a limited distance in waves of translation, and that in the actual distinction and the reason of the distinction between a wave of translation and an ordinary wave of oscillation.

For instance, a tidal wave which is a wave of translation goes from New York Bay to Albany or Troy in about 12 hours, 12 or 13 hours, a distance of 150 miles, or at the rate of 12 to 15 miles per hour; much faster in the deep water and much slower in the shallow water, and it is succeeding high tide at New York when the preceding high tide has reached Albany; there is a succeeding high tide at New York, and low water between, down in the vicinity of Poughkeepsie. It is utterly impossible for the water to actually travel from New York to Albany and Troy this 150 miles, in the course of 12 or 15 hours.

Q. But it has held back the flow of the Hudson River

there, and has changed the direction of flow in that time, hasn't it?

A. The flow of the Hudson River is impounded to a certain extent by the incoming tide,—held back, but at such times as the tide is characteristic at Troy or Albany, the flow is relatively small.

Q. You gave certain opinions as to the time it would take to start a flow of 10,000 cubic feet a second down the Drainage Canal, assuming that you have a uniform flow of 4167 cubic feet. Suppose your gates, traps, are open at Lockport to admit a flow of 14,000 cubic feet a second, how long would it take them to get the flow so started in that direction that it would take care of 10,000 cubic feet, assuming that that is coming from rain or storms and coming in through the Chicago sewers, or the sewers in the Sanitary District, or from run-off in the Sanitary District, and running into the Canal where it would naturally come?

A. I know of no way in which that matter could certainly be computed from theoretical presumptions or data. And the opinion that I gave in respect to the matter was an inference or analogy from experience that, for instance, a movement like a tidal wave would pass through the canal from Lockport to Lake Michigan, or vice versa, in perhaps an hour and a half. There are some data to indicate that it has traveled 20 miles of that distance in about 55 minutes. But that of itself does not represent the establishment of a regimen due to a change in condition. I am certain that it would take at least 12 to 14 hours, and it might take double that time to establish a flow.

Q. By that you mean it would take practically that long to clean out the water in the Drainage Canal and get a new quantity of 10,000 cubic feet a second?

A. Yes, sir, you must draw off the storage in the channel above the hydraulic grade that you are to establish, and you must get that water in complete motion from one end to the other, and there must at least be sufficient time for the water to travel the whole length of the canal, and then some.

Q. Suppose after that tidal wave, that you speak of that might travel the canal in an hour and a half, had passed to the lake from Lockport on an opening of 14,000 cubic feet a second of flow, in which the water should come into the canal, say at Robey street, somewhere along the canal, or it was added to the canal at various places, wouldn't the tend-

ency of that water after the wave had passed be to go towards Lockport?

A. Yes, sir, so far as any wave is concerned that is likely to be produced at Lockport, it would be just a heap of water traveling, and even the water on the top of the wave itself might be running the opposite direction. It is a pulse rather than the transference of a large body of water; but to establish a regimen of steady flow there under the conditions that you have stated, involves a large element of time. I will illustrate by some experiences I have had in a matter of that character.

Q. Before you go into that, I do not understand what you mean by regimen of steady flow. What I am trying to get at is the practical condition of water coming into the river regardless of steady flow, whether or not it would not go towards Lockport. Maybe I do not understand your terms?

A. Perhaps my mind shot by a little. Until such time as the volume of water that might be contributed from these sewers and from tributary water courses had exceeded this flow of 4167 feet, which you mention in your question, it certainly would travel towards Lockport. That when the volume contributed from the local watershed did exceed that, part of it would travel towards the lake until such time as the increment of flow was sufficient to take care of it. Is that responsive?

Q. You think that would take 12 hours?

A. Yes, sir.

Q. That any water in excess of 4,167 cubic feet a second, contributions that made the flow in the canal more than 4,167 cubic feet, would flow, some of it would flow into the lake?

A. Yes, sir.

Q. Within the 12 or 14 hours?

A. Yes, sir. It is my idea that, with the qualifications that I have made, the subject is difficult of computation and that experience itself,—an experiment is the best criterion that you would not produce a change at Chicago from opening the channel up at the lower end in less than about 12 hours, and perhaps considerably more.

Q. Haven't there been certain experiments made which show that it takes less time for the effect to be felt; or do you know?

A. The Sanitary District has made a series of experiments respecting that matter, but I have not had time to ex-

amine to see what the actual results are. The matter has been in charge of other engineers of the District, who I will presume will give you the information.

Q. There have been cases when a boat was stuck in the river, and the flow stopped at Lockport?

A. Yes, sir.

Q. How long does it take the effect of that stoppage at Lockport to be felt in the level where that boat is, say in the Chicago River?

A. I think it has usually taken about 12 hours.

Q. For it to be felt at all. The first wave would not lift that?

A. This wave is not always produced, this impulse that I speak of. It depends upon whether the controlling works are manipulated in such a manner as to produce it. It is rather an incident than an habitual occurrence, as I understand it.

Q. Suppose observations are made by an engineer measuring the current with the current meter, and he observes a certain crest at one point along the canal, and someone else at another point further down the canal observes when it gets there, that volume of flow that corresponds to it, and the time was taken, couldn't they determine that in that way,—or wouldn't that determination show that the water had passed from one place to the other?

A. They might have caught one of these swells or impulses, which we call a wave of translation, and those travel very long distances at times. They show up on gage records and specially automatic gage records and profiles of water surface, but they do not represent an actual transfer of water in any large volume beyond what is involved in producing the swell itself.

Q. Do those things take place in a canal like the Chicago Drainage Canal, say eight or ten miles down the canal produced by a greater inflow at the lake or outflow at Lockport, or vice versa?

A. I have not given any particular study to such phenomena in the Drainage Canal further than to be appraised of the fact that swells have been ooccasioned by opening and closing the Bear Trap Dam, which have been noted at points above; and have taken the trouble to apply the ordinary formula in regard to waives of translating to such phenomena for the purpose of checking it up, and found that they agreed as closely as such results usually do; closely enough to identify it as a wave of translation.

I started out to make a statement respecting an actual case with which I was connected on the St. Joseph River at South Bend, Michigan. There was very extended litigation between the South Bend Water Company and the Mishawaka Power Company. There was an intermediate pool of four miles, where the mean depth was 4 to 6 feet. The question involved was the question of backwater. They had a tainter gate at the lower dam which could be lowered by a number of feet, which was actually lowered two feet.

Mr. Adcock: Q. A regulating gate, you mean?

A. Yes, sir. Under the direction of the [illegible] they had gages established at all points, or a great number of points, eight or ten points along this four miles between the South Bend Dam and the Mishawaka Dam. It took six hours to establish a regimen of steady flow of four miles. Then on reversing the dam and putting it up again, it took six hours to re-establish the former record, before all the gages reached a condition where they were unchanged, where they remained steady; whereas a wave of translation would travel the length of that pool in about 15 to 20 minutes.

Mr. Hopkins: Q. How deep did you say that was?

A. It varied in depth. Without referring to the record, I would not say definitely, but the mean depth was 4 to 6 feet, generally speaking.

Q. As a matter of fact, doesn't that movement depend very largely, the speed of the movement depend almost entirely upon the depth?

A. Yes, sir. That is the only element that is involved in the formula, is the depth and the gravity. And with a depth of four to six feet, a tidal wave would have traveled through that pool in 15 to 20 minutes, over that four miles.

Q. Now suppose that depth had been 22 feet for that six miles, how long would it have taken in your opinion to have changed the entire regimen?

A. It would have adjusted itself more quickly.

Q. Can you give the proportion?

A. No, sir, I would not undertake to do so without—

Q. It would be in direct proportion to the depth, or doesn't the speed increase with the depth?

A. Most—

Q. Greater than in a direct proportion?

A. In impulse movements through water, speed varies as the square foot of the depth, but in establishing a regimen, I do not know that I have seen in any of the works a complete analytical discussion of the subject matter, and it is

a very illusive and difficult one to analyze. And it usually is so much easier to make the actual experiment than it is to figure these things out that that recourse is taken where the matter is involved.

Q. When you speak of establishing a regimen, you mean establishing a steady flow of the greater or the lesser amount?

A. Yes, sir, when the river—

Q. You do not mean to say that it takes that full length of time though for the flow to be started in that direction, and any contributions along the way would go that way?

A. What the French call entrain, everything running in order according to the hydraulic principles; whereas in the St. Joseph experiment, it took six hours to establish a condition entrain or in regimen. The closing of the dam probably produced some effect in a shorter time; how much shorter I don't now recall, but the effect was not complete until six hours had passed by and the full regimen had been established.

Q. Now, within that full six hours, say, in the St. Joseph case, when you have established your regimen, that would take your full increased flow—

A. 14,000 feet complete through the channel.

Q. Complete, but that would take it beginning at the source of it, wouldn't it?

A. Sure.

Q. It would take certainly a relatively a shorter time where some of the water comes in at intermediate stations wouldn't it, where the effect is traveling towards the source?

A. That would have the effect, of course, of shortening actually the channel, and would take place in a shorter time depending on where the water was supplied. But I wish to say that in any opinion upon a matter of that kind further than that the results are much longer deferred than usually anticipated, I think the true criterion is to experiment with it rather than to attempt to estimate it from any analytical data or analyses that we may have.

Q. Then you would not lay more stress on these theoretical opinions as compared with actual observations?

A. No, sir. No, sir, I do not. So I stated what I have stated in the matter with that caution, as merely an opinion; expressing the idea that a considerable length of time would be involved.

Re-direct Examination by Mr. Adcock.

Q. I will ask you this question, Mr. Cooley: If the Calumet Sag Channel when completed with a 2,000 foot capacity will not serve also to dilute the sewage of a population in addition to the sewage of the population of the Calumet District alone, the 134,000 that you speak of?

A. It will do so to the extent of its excess capacity. It joins the Main Channel only eight or ten miles below the city limits, and the surplus water is available at that point for dilution.

Q. And that would be the dilution of sewage of a population arising in that portion of the Sanitary District tributary to the Main Channel and the Chicago River?

A. Yes, sir, that would be true.

Q. And the dilution capacity of the flow of 2,000 second feet, would be approximately 600,000 people, wouldn't it?

A. Under the law, 2,000 seconds feet is the equivalent of 600,000 population.

Mr. Hopkins: Q. Under the law, you mean the State law?

A. Sanitary District law.

Mr. Adcock: Under the organic Act?

A. Yes, sir.

Q. The capacity of 2,000 feet per second of the Calumet-Sag Channel, as compared with 1,000 feet per second, will serve to reverse the flow of the Calumet River during the greater portion of the year?

A. It would be more effective. The time when the Calumet River exceeds a flow of 2,000 second feet is limited; and it would be more effective than a smaller channel; and coupled with a proposition which has always been considered in connection with the Calumet, which is the diversion of the upland waters directly to the lake, it would be sufficient to take care of the flood waters on the urban district and keep the water out of the lake at all times.

Q. It is your understanding at the present time there is a project being carried out of draining approximately 350 square miles at the headwaters of the Little Calumet?

A. Yes, sir the project known as the Byrne Ditch, has actually been under way, been started.

Q. There is a drainage district formed?

A. A drainage district, to drain the lands of the Upper Calumet direct to Lake Michigan, and to divert about half of its watershed. That same idea has been one of the early

considerations, and was analyzed by the Expert Committee of 1901 as a proper proposition in connection with the Calumet-Sag Channel; and I expect eventually to see it carried out.

Q. You spoke of the per capita consumption of water in Berlin, that it was about one-fourth to one-fifth of that in Chicago?

A. That is about correct.

Q. What bearing does that condition have upon works, or a plant in connection with sewage farming, such as they have at Berlin?

A. There is a limit to the amount of water that you can put on an acre of ground; and that limit is less where the rainfall is greater. As I stated, the rainfall at Chicago is practically 50 per cent. in excess of Berlin, which in itself would call for a larger area. The water supply being four times and upwards per capita that of Berlin, it would probably require at Chicago from five to six times as much area to take care of the sewage and raise crops at the same time as at Berlin.

Q. For the same population?

A. For the same population, yes.

Q. Then you spoke of the different climatic conditions, such as extreme temperatures here, as compared with even temperatures in Germany?

A. I have already stated that the rainfall is much less, which lends itself to sewage farming, and the summer temperatures are lower and the winter temperatures higher than here, less range in temperature which is also helpful.

In other words, works here would be maintained with much more difficulty during the winter season than at Berlin. And in the summer time, too, owing to excessive temperatures, the sewage would be less stable in the conduits and in the carriers. The nuisance would be greater here.

Q. You are familiar with the history of the sewage farm at Pullman, aren't you Mr. Cooley?

A. Yes, sir, I knew about it at the time, and was later associated with the man who designed those works, Mr. Benizette Williams, for The Pullman Company; and actually laid out some of the later additions to the Pullman sewers. They started out and constructed a complete model sewage farm at Pullman, and it was in operation as early as 1885, as I recall; a little earlier than that. But it was practically out of use after four or five years.

Q. And that served a comparatively small population, didn't it?

A. It served a comparatively small population, and the separate system was installed there; and the conditions were extremely favorable to an experiment of that kind.

Q. That is so far as this city is concerned?

A. Yes, sir. And in that case, in order to overcome temporary propositions, they conducted the sewage under ground, distributed the sewage to the land by hydrants, so that it would not freeze up; adopted other precautions that are not adopted on foreign sewage farms. Their works are more in the open. But it was found that market gardeners did not like to use the effluents. They could do just as well or better, and so there was really no market, no rental for the lands. They virtually used it for intermittant filtration for a time, and then even abandoned that; got rid of their sewage eventually in the easiest way possible by letting it go to the natural water courses.

Q. From your observations in England with reference to the Manchester District and the Ship Canal that you spoke about, the climatic conditions are better there than they are in this country, aren't they, in this city?

A. The climatic conditions in England are almost ideal. There is seldom a snowfall or ice. The winters are mild and the summer temperatures are moderate, rarely going above 70 to 80. The conditions are very favorable in the avoidance of extremes, both of freezing weather and of high temperatures with rapid sewage decomposition.

There are various methods used, practically all the methods that have been discussed, contact beds, sprinkling beds and chemical works for precipitation.

Q. And they treated the storm waters, didn't they?

A. Those methods are all used in the Manchester District, and they also handle the storm waters on bacteria beds before allowing the effluent to go into the canal; that is from the urban districts.

Q. Rainfall is distributed more evenly over the entire year; that would be a condition favorable also?

A. Yes, sir, the rainfall is distributed more evenly and the rainfall is also less and flood volumes are less than here. The problem is mitigated in all its range, in every direction.

Q. Now from your experience and observations, do you consider it likely with the rainfall here at Chicago, that there would be liable to be a large amount of water flowing into

the Chicago River at some point between say Robey Street and the mouth of the river, coming from sewers, the North Branch, and other points in the District?

A. Yes, sir.

Q. Now assuming that the flow was 4167 cubic feet per second, limited to that amount, would a condition be produced by such rainfall before the flow could be increased, so that the water coming from this drainage area would flow partly into Lake Michigan through the Chicago River, and partly down the Drainage Canal towards the Des Plaines River?

A. I think that condition would be produced under existing conditions before it would be possible to sufficiently increase the flow to care for it; and with the further development of the urban district, the carrying out of drainage schemes in the natural water sheds outside of the sewage district, the quickness of that flow will be increased and the peak will also be increased.

In other words, the problem will be accentuated by the extension of sewer systems, and pavements, and houses, and by complete drainage works throughout the District.

Re-cross Examination by Mr. Hopkins.

Q. What is the population of the Calumet District at the present time, Mr. Cooley?

A. In 1910, it was 134,000 in Illinois and 63,000 in Indiana.

Q. That part of it in the Sanitary District of Chicago is 134,000?

A. 134,000.

Q. And the canal that is being constructed down there now will take care of 600,000?

A. Adequate for 600,000. I would say that the projects that I originally opposed so vigorously in that region were for an estimated population of 1,200,000.

Q. And it was an estimated flow of 4,000 cubic feet a second?

A. Yes, sir.

Q. And this is for a flow of 2,000?

A. 2,000 feet. I will say further that there has been some change in the situation. There has been a joint problem of the State of Indiana, and the Indiana Legislature has within the last year and a half authorized the formation of a district in the State of Indiana, with the idea of co-operating

in a mutual problem with the State of Illinois, and making available this larger channel.

Q. There are times, or have been times when the Calumet River has a flow of as high as 15,000 cubic feet a second, hasn't it?

A. I think actual measurements have been made over 13,000 and estimates have been made that it might reach a maximum of 15,000. I think I have made those estimates myself.

Q. Are those days of flood time in that region any more or less numerous than flood times in the Chicago River, or would you say about the same?

A. Well, yes, about the same.

Q. How many days in a year on an average do you think that the flood in the Calumet River would exceed 2,000 cubic feet a second?

A. I don't know that I have any positive data upon that subject. I think it can be had, though. I think a gage has been kept at Riverdale by which some positive information can be given.

Q. It will be a great many more days than the flow in the Chicago River, normal flow would exceed 4,167 cubic feet a second, wouldn't it?

A. That is the volume there would exceed 2,000 feet for more days than the Chicago River would exceed 4167?

Q. Yes? Chicago River drainage area, I have in mind?

A. Yes. Answering offhand, I would say yes, with qualifications; that we have a tremendous built up area in Chicago that does not exist in the Calumet, and we have a very large area of swamp in the Calumet, which does prolong the flow there. Off of this built up area and pavement, two or three times the relative volume of water comes over that which comes from lands, so to answer that on the basis of areas and time might be misleading.

Q. I will ask another question, which I should have asked before: You did not make a detailed study of the river measurements, observations, made by the Lake Survey men that has been testified to in this case, did you?

A. No, sir.

Further Re-direct Examination by Mr. Adcock.

Q. Take the Calumet situation there, if the intercepting sewers and sewer systems in that locality are so constructed that no sewage is deposited in the Calumet River itself, and that all the sewage is deposited beyond the controlling works into the Sag Channel, which will prevent its going into the Calumet River or the Little Calumet River, the reversal of the Calumet River itself is not so important or so serious as the reversal of the Chicago River where there are great areas of paved streets draining directly into the river?

A. Why it would be far less important, of course, if the problem is treated in that way. And it goes without saying that under the conditions of drainage in the Calumet, it must either be treated in that way or the upland water must be diverted so as to reduce the local drainage to the capacity of the channel.

Q. This Byrne Ditch will reduce the number of days, will it not of excess flow?

A. Yes, the Byrne Ditch will handle part of the problem. The example can be followed until practically all the upland waters outside the urban district can be diverted; and is it feasible to reduce the proposition in the Calumet region, so that there will be no effluent into the lake. That is the channel which has been constructed will be adequate for what will remain. That is feasible, and that I consider the best possible remedy. On the other hand, an alternative is the construction of the intercepting sewers which will remedy it to the extent that the sewage itself pillutes the river, but not to the extent that the river may be polluted extraneously.

Q. The mouth of the Calumet River is very much further from the intakes for the general water supply of Chicago than the mouth of the Chicago River?

A. Yes, sir, it is much more remote. In fact there is only one of the general intakes of Chicago that is nearer than six miles to it, I think.

Adjourned subject to notice.